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LIMITED
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296

Systems and Instruments

for

Production Testing

Quality Control

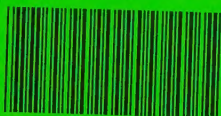
Calibration

Research

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MP MASTER



MA29519

Electro Scientific Industries

13900 N.W. Science Park Drive
Portland Oregon 97229



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WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

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SECTION 1

DESCRIPTION

1.1 INTRODUCTION

Model 296 is a microprocessor-controlled automatic LRC meter. It performs high speed L, R, C, and G measurements and also calculates D and Q. Its two 4-1/2 digit readouts simultaneously display the reactive and loss components of the unknown. Measurement function programming is performed with the 24-button front panel keyboard which uses dual function buttons similar to those in pocket calculators to simplify function selection.

A wide range of features and options give the user maximum flexibility to tailor instrument operation to specific testing requirements. Model 296 operates as a stand-alone benchtop tester or can be used with auxillary handling equipment and easily fits into sophisticated automatic testing systems. Section 1.3 is a feature summary which lists features and the instruction manual section describing them.

1.2 SPECIFICATIONS

ADMITTANCE	C BRIDGE RANGE NUMBERS		0	1	2	3	4	5	6	7	8
	RANGES FULL SCALE	C_p, C_s 1 kHz	19.999 mF	1.9999 mF	199.99 μ F	19.999 μ F	1.9999 μ F	199.99 nF	19.999 nF	1.9999 nF	199.99 pF
		120 Hz ^①	199.99 mF	19.999 mF	1999.9 μ F	199.99 μ F	19.999 μ F	1999.9 nF	199.99 nF	19.999 nF	1999.9 pF
		G_p 1 kHz and 120 Hz ^①	100.00 S	10.000 S	1.0000 S	100.00 mS	10.000 mS	1.0000 mS	100.00 μ S	10.000 μ S	1.0000 μ S
	R_s 1 kHz and 120 Hz ^①	19.999 m Ω	199.99 m Ω	1.9999 Ω	19.999 Ω	199.99 Ω	1.9999 k Ω	19.999 k Ω	1.9999 M Ω		
	TEST SIGNAL	HI Voltage LO Voltage	0.001 VRMS 0.01 VRMS 0.1 VRMS	1 VRMS							
ACCURACY ^② $\pm$ (% of Reading + % of Full Scale)	HI Voltage LO Voltage	$\pm[2.0\% + (0.05\%)^{\textcircled{3}}]$ $\pm[0.5\% + (0.025\%)^{\textcircled{3}}]$	$\pm[0.1\% + (0.005\%)^{\textcircled{3}}]$								
	$\pm[0.1\% + (0.01\%)^{\textcircled{3}}]$										
SPECIAL C_s RANGE 120 Hz ^①		0.2 F to 2 F Manually Selected					Accuracy: $\pm 5\%$ of Reading				
IMPEDANCE	L BRIDGE RANGE NUMBERS		1	2	3	4	5	6	7	8	
	RANGES FULL SCALE	L_s, L_p 1 kHz	19.999 μ H	199.99 μ H	1.9999 mH	19.999 mH	199.99 mH	1.9999 H	19.999 H	199.99 H	
		120 Hz ^①	199.99 μ H	1999.9 μ H	19.999 mH	199.99 mH	1999.9 mH	19.999 H	199.99 H	1999.9 H	
		R_s 1 kHz and 120 Hz ^①	100.00 m Ω	1.0000 Ω	10.000 Ω	100.00 Ω	1.0000 k Ω	10.000 k Ω	100.00 k Ω	1.0000 M Ω	
	G_p 1 kHz and 120 Hz ^①	19.999 S	1.9999 S	199.99 mS	19.999 mS	1.9999 mS	199.99 μ S	19.999 μ S	1.9999 μ S		
	TEST SIGNAL	HI Current LO Current	100 mA 10 mA		10 mA	1 mA	100 μ A	10 μ A	1 μ A		
ACCURACY ^② $\pm$ (% of Reading + % of Full Scale)	HI Current LO Current	$\pm(0.1\% + 0.05\%)$	$\pm(0.1\% + 0.005\%)$						$\pm(0.5\% + 0.05\%)$		
	1 kHz LO Current		$\pm(0.1\% + 0.01\%)$						$\pm(0.1\% + 0.05\%)$		
	120 Hz HI Current		$\pm(0.1\% + 0.025\%)$						$\pm(0.5\% + 0.1\%)$		
	LO Current		$\pm[0.1\% + (0.025\%)^{\textcircled{3}}]$						$\pm(0.5\% + 0.25\%)$		
DISSIPATION	D RANGE, FULL SCALE		1.9999								
	ACCURACY $\pm$ (% of Reading + Counts)	HI Test Signal LO Test Signal	$\pm(2.0\% + 20 \text{ Counts} + A^{\textcircled{4}})$	$\pm(1.0\% + 10 \text{ Counts} + A^{\textcircled{4}})$	$\pm(1.0\% + 5 \text{ Counts} + A^{\textcircled{4}})$						$\pm(1.0\% + 10 \text{ Counts}^{\textcircled{4}} + A^{\textcircled{4}})$
Q	Q RANGE, FULL SCALE		1999.9								
TEMPERATURE COEFFICIENT OF ACCURACY	23°C C, L, G and R $\pm 5^\circ\text{C}$ D and Q	$\pm(0.01\% \text{ of Reading}/^\circ\text{C} + 0.001\% \text{ of Full Scale}/^\circ\text{C})$									
		$\pm(0.01\% \text{ of Reading}/^\circ\text{C} + 0.3 \text{ Count}/^\circ\text{C})$									

① 100 Hz for 50 Hz line frequency

② C and L derating for large loss:
±(0.05% of full scale) (counts of G, D, or R/10,000)

③ Multiply by 2 for 120 Hz or single cycle measurement

④ Multiply by 2 for 1 kHz and by 4 for 120 Hz or single cycle measurement

$$⑤ A = \left(\frac{20,000}{C \text{ or } L \text{ reading}} \right) (0.3 \text{ count})$$

$$A = \left(\frac{20,000}{C \text{ or } L \text{ reading}} \right) (0.03 \text{ count}) \text{ for low D mode}$$

⑥ Multiply by 5 for 120 Hz or single cycle measurement

Table 1-1. Model 296 Specifications

Zero Adjustments: L - ±0.1 μ H; R - ±1m Ω (HI frequency only)
C - ±20pF; G - ±50nS (compensates for lead and test fixture effects)

Measurement Speed (See Figure 2-4): 1kHz - as low as 88ms
120Hz - as low as 133ms

Displays: Two, 4-1/2 digit, LED, with units symbols

Keyboard: 24-button (22 dual function keys)

Power: 120VAC (100, 220, 240VAC optional), 60Hz (50Hz optional), 100W

Continuous or Single Cycle - continuous measurements or single measurement cycle, with or without digital averaging; see Sections 2.3.1.2 and 2.3.9

Deviation Measurement - either percent or absolute deviation from a nominal; see Section 2.3.5

Multi-Limit Sorting - 10 limits for sorting components into tolerance bands, either percent or absolute limits; see Section 2.3.6

Digital Averaging - displayed value is calculated mean of 8 measurements; see Sections 2.3.1.2, 2.3.8 and 2.3.9

Test Mode Functions - alternate programming mode providing additional functions and alternate choices for standard functions; see Section 2.3.9

Active Guard - for measuring components in closed loop and buried node configuration; see Section 2.3.1.5

Front Panel Lock-out - eliminates accidental change of test conditions and functions; see Sections 2.3.9 and 2.4.3

External Bias to 200V - allows bias for electrolytic and tantalum capacitors; see Section 2.3.10

Charged Capacitor Protection - prevents damage if charged capacitor is connected to test leads; see Section 2.3.3

Front and Rear Panel Guarded Four-terminal Connections to Unknown - see Section 2.3.1.3

OPTIONS (Field-Installable)

IEEE 488-1975 Interface (GPIB) - allows operation with external equipment and controllers; see Section 2.4.3.1

High Speed Measurement - increases overall measurement speed; see Sections 2.3.8 and 2.4.2

DC Resistance Measurement - allows measurement of resistance with dc signal; see Section 2.4.1

Handler Interface Kits - for operation with high speed parts handlers; see Section 2.4.4

Teletype Interface - for operation with serial bus devices with current loop, RS 232, or TTL levels; see Section 2.4.3.2

Card Reader Interface - simplifies programming and eliminates operator error; see Section 2.4.3.3

SECTION 2

OPERATION

2.1 FRONT PANEL CONTROLS

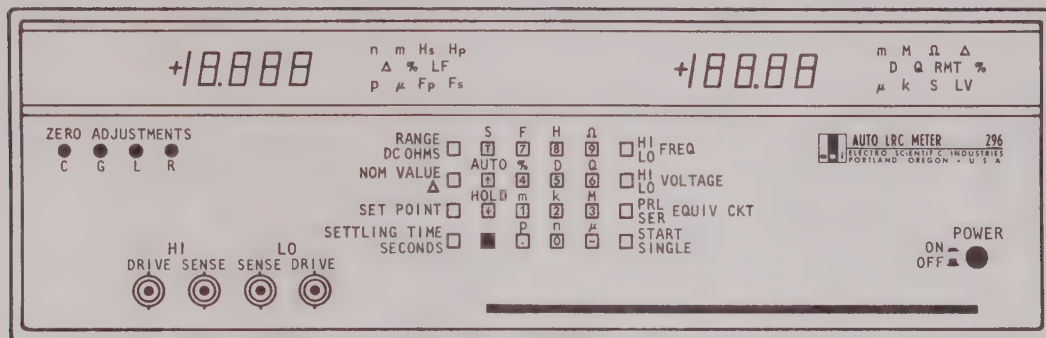


Figure 2-1. Model 296 Front Panel

2.1.1 Keyboard

The keyboard provides all control functions for Model 296. It consists of 24 buttons, 22 of which have two functions. Buttons with two functions have the alternate function represented in red lettering on the front panel. To select an alternate function, the red button must be pushed before the button with the desired function. The function of each button is described below.

- ./p - Decimal point and pico (10^{-12}) multiplier.
- 0/n - Zero numeral and nano (10^{-9}) multiplier.
- /μ - Minus sign and micro (10^{-6}) multiplier.
- 1/m - One numeral and milli (10^{-3}) multiplier.
- 2/k - Two numeral and kilo (10^3) multiplier.
- 3/M - Three numeral and mega (10^6) multiplier.
- 4/% - Four numeral. % key is used with the limits and deviation features to define and display % deviation.
- 5/D - Five numeral. D represents dissipation factor measurement function.
- 6/Q - Six numeral. Q represents quality factor measurement function.
- 7/F - Seven numeral. F represents farads (the units of capacitance) and capacitance measurement function.
- 8/H - Eight numeral. H represents henries (the units of inductance) and inductance measurement function.
- 9/Ω - Nine numeral. Ω represents ohms (the units of resistance) and resistance measurement function.

The above buttons are used to set ranges, desired units of display, and measurement functions. Multipliers allow combinations such as mH (millihenries) and nF (nanofarads) to be programmed. The ., - and 0 thru 9 keys are for setting ranges, nominal values, set points and other functions which require input of a specific number.

T/S - The S function provides the units for conductance (siemens) and selects that measurement function. T represents TEST. Pushing this button lights all the numerical displays as a check for burned out segments. It is also used to enter special test mode measurement functions. (See Section 2.3.9.)

↑/AUTO and ↑/HOLD - AUTO and HOLD refer to autoranging and range hold modes. Autoranging is automatically selected when the unit is first turned on. HOLD mode allows rapid checking of many unknowns in the same range. When in the HOLD mode, the ↑ and ↓ shift Model 296 up and down ranges. Pushing the ↑ or ↓ button when in AUTO mode puts the instrument in HOLD mode and shifts the range. AUTO returns unit to autoranging mode.

HI/LO FREQ and HI/LO VOLTAGE - Select the high and low test frequency and test voltage or current. High frequency is 1 kHz, low is 120 Hz (100 Hz for 50 Hz line frequency). High and low voltage and current settings are shown in Table 1-1.

PRL/SER EQUIV CKT - Selects parallel or series equivalent circuit measurement modes.

NOM VALUE/Δ - Sets the nominal value for deviation measurement. Δ selects absolute deviation.

SETTLING TIME/SECONDS - Function select and units for programmable settling time.

RANGE/DC OHMS - Begins range and function setting procedure, stops measurement, and turns off display. Measurement resumed by pushing START button. DC OHMS selects dc resistance measurement function when optional PC board is installed.

START/SINGLE - Begins measurement after it has been stopped by setting function and range. SINGLE makes one measurement and holds display.

Red Button - Selects alternate function of two-function buttons.

SET POINT - Sets limits bands for limits feature. Advances limits band to next band and prepares instrument to accept numbers and units for that band. Red button SET POINT toggles between indicating band number and normal measurement when set points have been entered.

2.1.2 Displays

The two 4-1/2 digit displays each have a set of units indicators which show the units and functions selected.

p, n, μ , m, k, M - Multiplier prefixes for the basic units programmed, such as nF (nanofarads) and mH (millihenries); p=pico, n=nano, μ =micro, m=milli, k=kilo, and M=mega.

Fp, Fs, Hp, Hs, Ω , S, D, Q, - Basic units for functions programmed: Fp=farads, parallel capacitance; Fs=farads, series capacitance; Hp=henries, parallel inductance; Hs=henries, series inductance; Ω =ohms (resistance); S=siemens (conductance); D=dissipation factor; and Q=quality factor.

LF and LV - Indicates the low frequency and low voltage modes have been selected.

RMT - Represents remote control operation. Remote operation is possible only when an interface option is installed. The front panel keyboard does not operate when the RMT light is on.

% - Indicates percent deviation display.

Δ - Indicates absolute deviation display.

2.1.3 Other Front Panel Controls

ZERO ADJUSTMENTS - The L, R, C and G zero adjustments on the front panel permit compensation for test fixture reactance (L and C) and loss (R and G) components (L and R zero function on HI frequency only).

HI and LO terminals - Four BNC connectors for guarded, four-terminal connection to the unknown.

POWER - Turns instrument on and off.

2.2 REAR PANEL CONTROLS

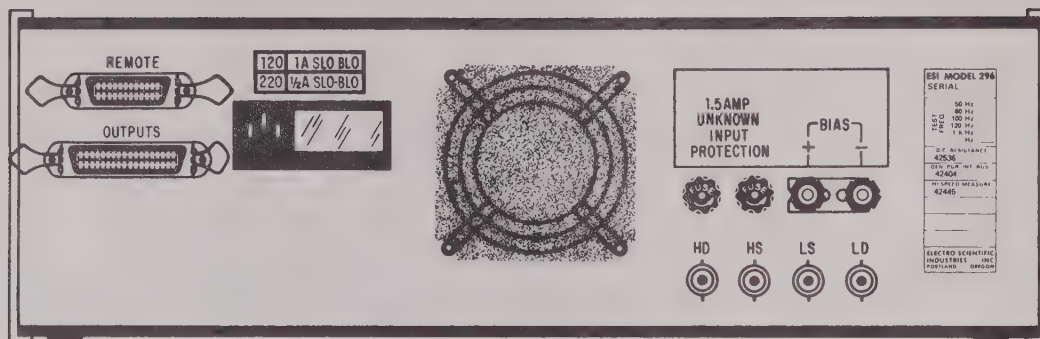


Figure 2-2. Model 296 Rear Panel

Line Cord Connector - The line cord connector meets IEC standards. It is fused and provides for selection of input voltage. It does not allow line frequency changes. Line frequency changes require replacement of internal components (see Section 2.3.2). Fuse ratings for 120 and 220 VAC input voltages are shown above connector.

REMOTE Connector - A 24-pin connector which allows connection to an interface option. Interface option required for operation.

OUTPUTS Connector - A 36-pin connector; outputs dependent on options.

HD, HS, LS, LD Connectors - BNC connectors for making guarded, four-terminal connection to unknown. Duplicates of front panel connectors. See Section 2.3.1.3.

BIAS - Terminals for connection of bias voltage up to 200V. Bias supply polarity must match terminal indications. When no bias supply is connected, terminals must be connected together with shorting lug provided. See Section 2.3.10.

Fuses - Protection for input. A 0.5A 3AG fuse prevents damage to instrument if a charged capacitor is connected to input terminals. See Section 2.3.3. A spare fuse is located adjacent to the bias terminals.

2.3 OPERATING INSTRUCTIONS

Operation of Model 296 is divided into four areas of control: Measurement functions, test signal, measurement mode, and measurement display. The operator may select one or more setting from each area to tailor the test conditions to the exact requirements.

MEASUREMENT FUNCTIONS

Model 296 measures two reactance functions and four loss functions as shown below. The reactances may be measured either as parallel or series equivalent components, as can D and Q. Resistance is a series equivalent circuit component, conductance is a parallel component.

<u>Function</u>	<u>Type</u>	<u>Units</u>	<u>Equivalent Circuit</u>
Capacitance	Reactance	farads (F)	Parallel/Series
Inductance	Reactance	henries (H)	Parallel/Series
Dissipation Factor	Loss	(ratio)	Parallel/Series
Quality Factor	Loss	(ratio)	Parallel/Series
Resistance	Loss	ohms (Ω)	Series
Conductance	Loss	siemens (S)	Parallel

TEST SIGNAL

The signal applied to the unknown has two parameters selectable by the operator, frequency and level, shown below. Each has a choice between a high and a low level. High frequency is 1kHz in the standard Model 296, low frequency is 120Hz for the standard unit. Test signal level is selectable between a high and low level which are dependent on range and function (see specification chart, Table 1-1).

<u>Test Signal Parameter</u>	<u>Level</u>
Frequency	HI (1kHz for standard unit) LO (120Hz for standard unit)
Voltage/Current	HI dependent on range and function LO (see Table 1-1)

MEASUREMENT MODE

Factors that influence the measurement cycle are grouped under measurement mode functions.

<u>Function</u>	<u>Alternate Choice</u>
Continuous Measurement	Single measurement cycle
Autoranging	Range Hold
Digital Averaging	No Averaging
Settling Time	Default (initial turn-on) Time or Programmed Value

MEASUREMENT DISPLAY

Results of measurements may be displayed in four different manners: Direct reading, units (absolute) deviation, percent deviation, and limits sorting. Direct reading display refers to display of actual quantity as measured in its correct units. Percent and absolute deviation of measured quantities are calculated from a set nominal value. Section 2.3.5 describes this display mode. Limits sorting is

also calculated from measured quantities. Limits are set by the user and the component is "sorted" into the appropriate limit band based on its measured value. See Section 2.3.6 for operation of limits display.

Function

Direct Reading
Units Deviation
Percent Deviation
Limits Sorting

Each of the four measurement control areas can easily be programmed with the front panel keyboard or remotely when an interface option is installed.

2.3.1 Basic Operation

Operating Model 296 is more similar to operating a pocket calculator than an impedance bridge. Functions are labeled on the front panel or on the buttons. Note that some buttons have labels for more than one reprint function. These are called dual function buttons. Functions labeled on the button or in white are selected by pushing the button. Functions labeled in red are selected by pushing the red button first, then the button for the desired function.

2.3.1.1 Basic Operation Outline

To begin measurements follow the steps outlined below. Details for each step are contained in the section noted.

1. Connect test leads to Model 296 (see Section 2.3.1.3, Connections to Unknown).
2. Adjust instrument for proper line voltage and frequency (if necessary; see Section 2.3.2) and plug line cord into receptacle.
3. Turn instrument on and connect unknown to test leads (see Section 2.3.1.3, Connections to Unknown).
4. Select desired functions and test conditions (Section 2.3).
5. Push START (or SINGLE) button to begin measurement.

NOTE: The instrument must be operated in its upright position because it contains mercury wetted relays. If it has been in another position (as can occur in shipping) the mercury must be shaken down by lifting the rear approximately 1/4 inch off the table and letting it drop. Do this three times.

2.3.1.2 Basic Instructions

When the instrument is turned on by depressing the POWER button, initial turn-on conditions are selected. Initial conditions for a standard unit for each of the four control areas are listed below.

Measurement Functions: S (Conductance)
Fp (parallel Capacitance)

Test Signal: HI FREQ (1kHz for standard unit)
HI VOLTAGE (see Table 1-1)

Measurement Mode: Continuous measurement
Autoranging
Digital Averaging
Default Settling Times (see Section 2.3.7)

Measurement Display: Direct Reading

Since the instrument is in autoranging mode, if the test leads are open (not connected to anything), Model 296 will range down to the lowest range. If the test leads are shorted together, the instrument will autorange to the highest range and the displays flash to indicate the overload condition. If a component is connected to the leads, Model 296 will select the proper range for the component (unless the component value is too large for the highest range, which causes the displays to flash, indicating overload).

Selecting Test Conditions

To change from the initial conditions, just push the button for the desired function (red button first if it is labeled in red). The order of selection is not critical. The following examples illustrate only a few of the possible combinations and orders of selection. Throughout this instruction manual, an asterisk (*) represents pushing the red button, e.g., *F represents pushing red button then F button.

Measurement Functions

		LOSS FUNCTIONS			
		S (parallel)	Ω (series)	D	Q
REACTANCE FUNCTIONS	PARALLEL	F	✓		✓
		H	✓		✓
	SERIES	F		✓	✓
		H		✓	✓

✓ = allowed combinations

Table 2-1. Function Combinations

Reactance functions are programmable independently from loss functions, within the allowable combinations. (See Table 2-1.) The appropriate series or parallel reactance function is automatically programmed when a loss function is selected. For example, the initial conditions are Fp and S. If the operator wanted to measure Fs (series capacitance) and pushed the SER EQUIV CKT button (*EQUIV CKT), S would no longer be measured. The series loss function, Ω (resistance), would be selected in place of the parallel loss function S (siemens).

Examples (*represents Red Button)

<u>Desired Functions</u>	<u>Sequence</u>
From Initial to Fs, Ω	*EQUIV CKT (Ω is automatically programmed for series function)
Change to Fs, D	*D
Change to Fp, D	EQUIV CKT
Change to Hs, Q	*H, *EQUIV CKT, *Q
Change to Hs, S	(Cannot program S with Hs or Fs because S is a <u>parallel</u> function only. When S button is pressed Hp is selected.)

Test Signal

Test signals may be changed at any time. Note that changing test frequency changes measurement range (see Table 1-1). When setting a specific range (such as in deviation or limits measurements), it is important that the desired test frequency be selected before the desired range to avoid accidental range change.

Examples:

	<u>Initial</u>	<u>Change To</u>	<u>Sequence</u>
Frequency	HI	LO	*LO FREQ
VOLTAGE	HI	LO	*LO VOLTAGE

Measurement Mode

Continuous measurement is the initial mode selected. To perform a single measurement press *SINGLE for each measurement required. To return to continuous measurement just press START.

Autoranging mode is selected when the instrument is turned on. To hold the instrument on a particular range, press *HOLD. To return to autoranging, press *AUTO.

To make repeated measurements of similar value unknowns, it is sometimes desirable to set a particular range. The following procedure selects and holds a particular range.

1. Push RANGE button. Measurement is stopped and bridge put in range hold mode.
2. Push buttons for numerals of range.
3. Push red button, then buttons for multiplier (μ , m, etc.) and measurement functions (F, Ω , etc.). (Multiplier and function are treated as one command, so the red button must only be pressed once for the pair, e.g., *nF not *n*F.)
4. Push START button to resume measurements.

Example: Set range for 50nF capacitor, push: RANGE, 5, 0, *, n, F. The displays show the 199.99nF range is selected.

NOTE: In the above example, the same range is selected if the digits 1, 0, 0 are pushed; any digits from 20 to 199 will select the 199 range. Digits for a range must be greater than 0.1999 to be valid. For instance, 0.019 causes the displays to flash and is not accepted as a proper range.

Digital averaging mode is programmed as initial condition. In this mode the displayed value is the calculated mean value of eight sample measurements. For a complete discussion of the digital averaging cycle see Section 2.3.8, Measurement Speed. Measurements without averaging can be programmed by either of two methods: Single cycle or special test mode (see Section 2.3.9). Single cycle is selected simply. It is the alternate function of START button (*SINGLE). Programming special test mode operations allows continuous measurements without digital averaging, single measurements with digital averaging or measurements with digital averaging of the loss component only. These and other special test modes are discussed in Section 2.3.9.

Settling Time

Settling time appropriate for the proper range chosen is programmed automatically. The user may select settling times to accommodate individual testing requirements. Section 2.3.7 gives more information on settling time.

Measurement Display

Initial turn-on display is direct reading measurement. Some of the initial conditions are indicated on the display, others are only indicated when the alternate condition is selected. The list below gives the initial display for the initial conditions.

	<u>Condition</u>	<u>Display</u>
Functions:	Capacitance (parallel)	Fp
	Conductance (parallel)	S
Test Signal:	HI frequency	NONE (LF displayed when LO selected)
	HI voltage/current	NONE (LV displayed when LO selected)
Measurement Mode:	Continuous measurement	NONE
	Autoranging	NONE
	Digital Averaging	NONE
	Settling Time	NONE

2.3.1.3 Connections to Unknown

Model 296 is a 6 terminal instrument. It provides separate shielded connection cables for current drive and voltage sense to the high and low side of the unknown and to the guard point. These cables are fully shielded to minimize zero capacitance. They are labeled HI DRIVE, HI SENSE, LO SENSE and LO DRIVE. GUARD DRIVE is the shield around HI DRIVE and GUARD SENSE is the shield around LO SENSE (see Figure 2-3 below). Drive and sense leads for each of the three sets must be connected together for accurate measurements.

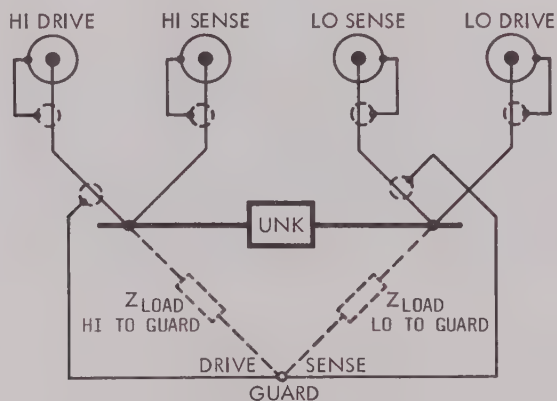


Figure 2-3. Connection to Unknown

Separate drive and sense connections are necessary to prevent lead resistance from becoming a part of the measured unknown. This is especially true for accurate measurements of low impedance unknowns. Separate drive and sense connections can be made to a single lead connected to the unknown if the lead is a small part of the unknown impedance ($R_{\text{lead}} < Z_{\text{unk}}/1000$ for $<0.1\%$ error). With proper connections as shown in Figure 2-3, for most measurements cable lengths up to 20 feet cause no loss of accuracy. Longer cable lengths or special test conditions may result in some accuracy loss. Consult ESI factory for advice on your application.

2.3.1.4 Front Panel Zero Adjustments

For accurate measurements (especially for units with optional test frequencies above 1kHz) it is necessary to cancel capacitance and inductance errors due to test leads and test fixtures. The standard cable set (ESI Part Number 23898) has been bundled for convenience in measuring mid-range unknowns. When measuring large capacitances (above 1000 μ F) or small inductances (below 1mH) best accuracy is achieved by modifying the cable set to insure proper cancellation of lead inductances.

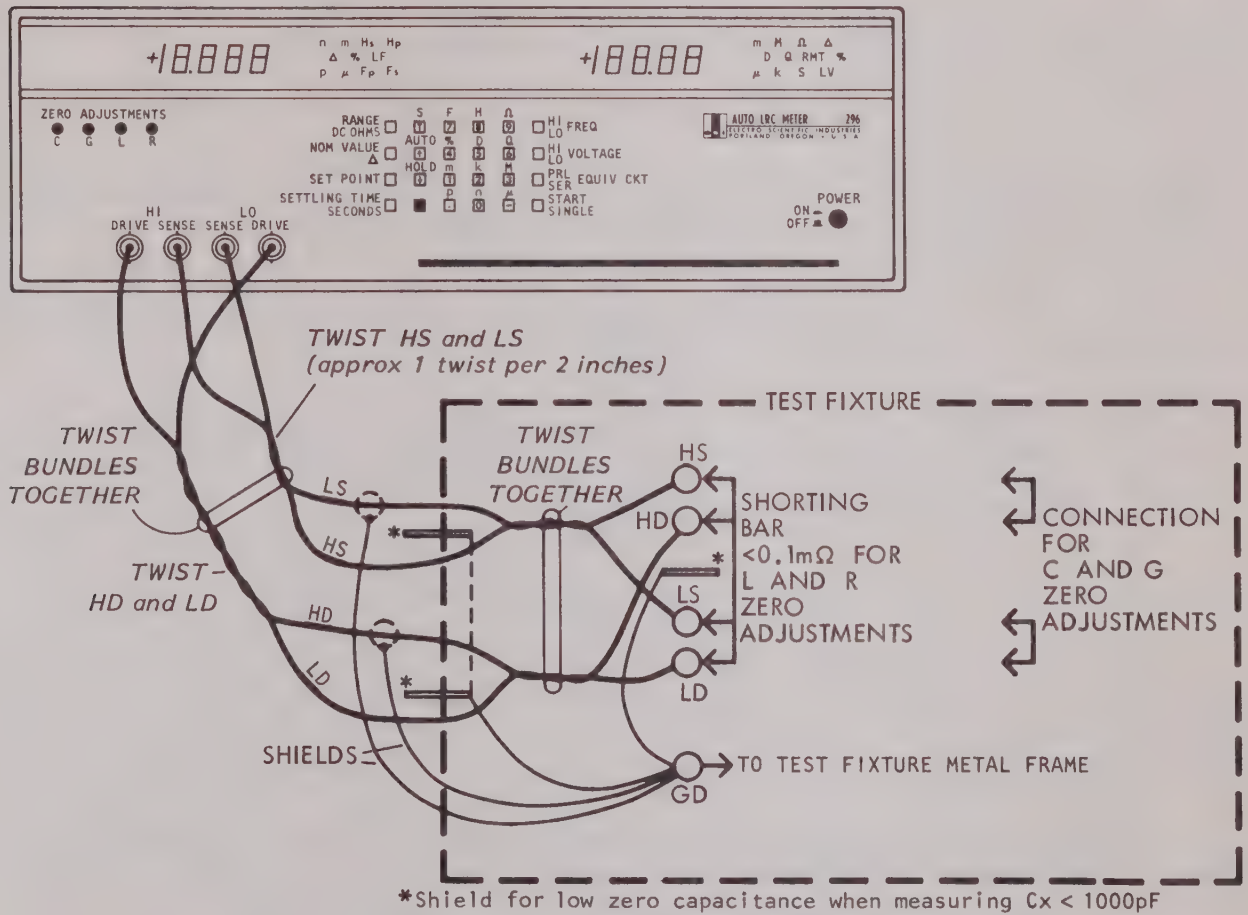


Figure 2-4.

Cable Set and Test Fixture Cancellation: (See Figure 2-4)

1. Cut the cable ties fastening the standard cable set and twist the shielded HI DRIVE and LO DRIVE cables together (approximately 1 twist per 2 inches).
2. Twist HI SENSE and LO SENSE cables together.
3. Twist these two bundles together then connect to fixture.
4. Connect guard (GD) leads together, then to metal frame of fixture.

Inductance: (Not necessary for earlier units without L and R trimmers. L and R trimmers are active at the HI FREQ setting only).

1. Connect a shorting bar ($<0.1m\Omega$) using a 4-terminal connection.
2. Set to LO FREQ, Hs, Ω and let unit autorange to lowest L and R range. If the inductance reading is more than ± 2 counts move one of the sense leads closer to one of the drive leads until the counts are near zero. Secure the leads in this position.
3. Adjust front panel L and R trimmers for zero on both displays with Model 296 set to the following functions:
 - a) HI frequency.
 - b) L Series (Ls), R series (Rs). (Push *H then * Ω .)
 - c) Lowest L and R range. (Unit will autorange to lowest range with shorting bar in place.)

Capacitance: (Not necessary for unknown above 1000pF)

1. Remove shorting bar.
2. Short LO DRIVE to LO SENSE.
3. Short HI DRIVE to HI SENSE.
4. Adjust front panel C and G trimmers for zero on both displays with Model 296 set to following conditions:
 - a) Frequency and test level set as desired.
 - b) C Parallel (Cp), G parallel (Gp).
 - c) Lowest C range.

An alternate method of eliminating the effects of zero inductance and resistance is to subtract them from the reading by using the deviation function as described in Section 2.3.5.

2.3.1.4 Front Panel Zero Adjustments

For accurate measurements (especially for units with optional test frequencies above 1kHz) it is necessary to cancel capacitance and inductance errors due to test leads and test fixtures. The standard cable set (ESI Part Number 23898) has been bundled for convenience in measuring mid-range unknowns. When measuring large capacitances (above 1000 μ F) or small inductances (below 1mH) best accuracy is achieved by modifying the cable set to insure proper cancellation of lead inductances.

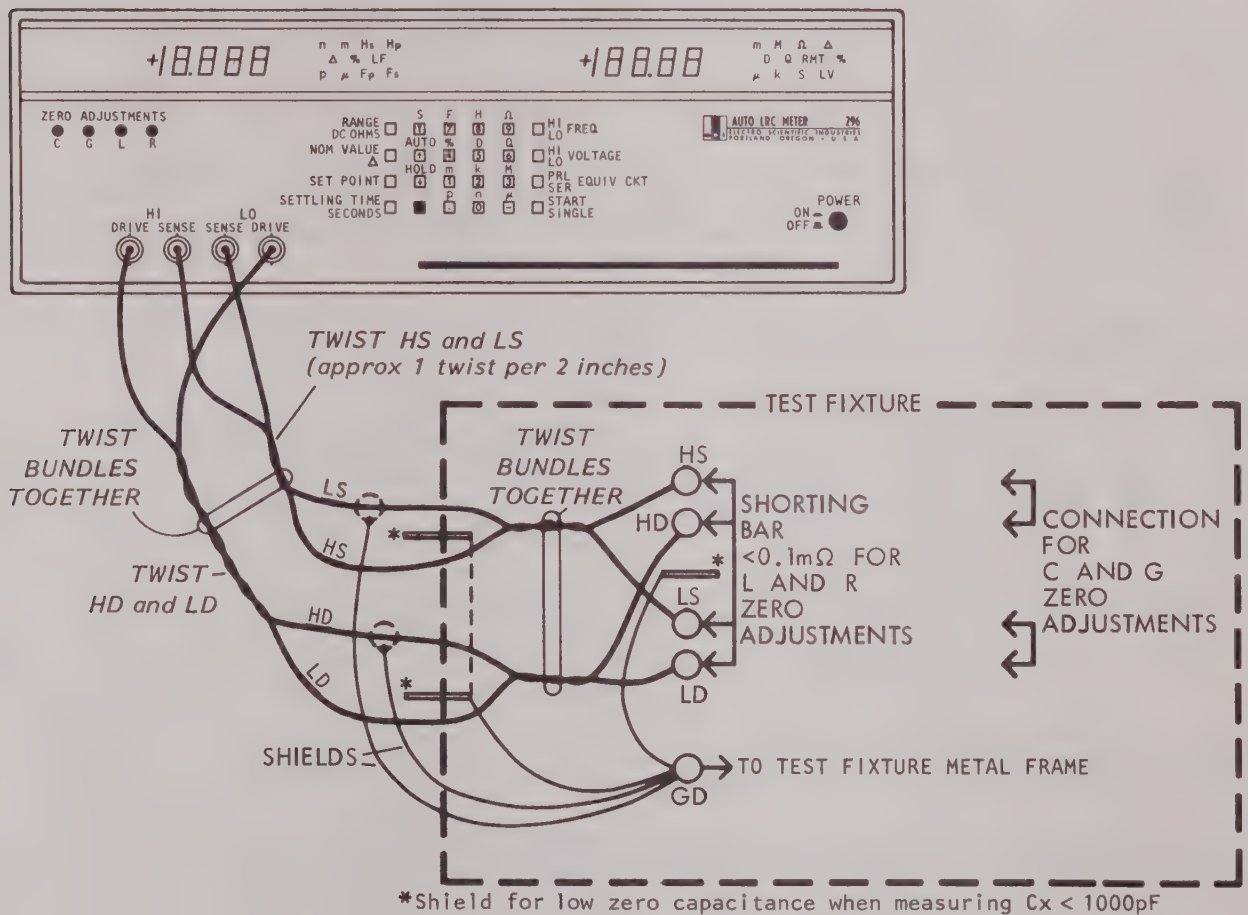


Figure 2-4.

Cable Set and Test Fixture Cancellation: (See Figure 2-4)

1. Cut the cable ties fastening the standard cable set and twist the shielded HI DRIVE and LO DRIVE cables together (approximately 1 twist per 2 inches).
2. Twist HI SENSE and LO SENSE cables together.
3. Twist these two bundles together then connect to fixture.
4. Connect guard (GD) leads together, then to metal frame of fixture.

Inductance: (Not necessary for earlier units without L and R trimmers. L and R trimmers are active at the HI FREQ setting only).

1. Connect a shorting bar ($<0.1m\Omega$) using a 4-terminal connection.
2. Set to LO FREQ, Hs, Ω and let unit autorange to lowest L and R range. If the inductance reading is more than ± 2 counts move one of the sense leads closer to one of the drive leads until the counts are near zero. Secure the leads in this position.
3. Adjust front panel L and R trimmers for zero on both displays with Model 296 set to the following functions:
 - a) HI frequency.
 - b) L Series (Ls), R series (Rs). (Push *H then * Ω .)
 - c) Lowest L and R range. (Unit will autorange to lowest range with shorting bar in place.)

Capacitance: (Not necessary for unknown above 1000pF)

1. Remove shorting bar.
2. Short LO DRIVE to LO SENSE.
3. Short HI DRIVE to HI SENSE.
4. Adjust front panel C and G trimmers for zero on both displays with Model 296 set to following conditions:
 - a) Frequency and test level set as desired.
 - b) C Parallel (Cp), G parallel (Gp).
 - c) Lowest C range.

An alternate method of eliminating the effects of zero inductance and resistance is to subtract them from the reading by using the deviation function as described in Section 2.3.5.

2.3.1.5 Measurement of Delta Networks (Active Guard)

Model 296 has the ability to accurately measure an unknown with impedances from either end of the unknown to a point that can be connected to guard (see Figure 2-3). The accuracy of the measurement is determined by how low these loading impedances are with respect to the unknown. The basic instrument accuracy for this type of measurement is maintained as follows:

1. Load impedance from HI to GUARD: for capacitance or conductance measurements - stated accuracy maintained for loads $>100\Omega$ (500Ω on range zero) for inductance or resistance measurements - accuracy maintained for loads $\geq 2Z_{unk}$.

2. Load impedance from LO to GUARD: for capacitance, conductance, resistance and inductance measurements - additional counts in left and/or right display =

$$[Z_{unk}/(Z_{load \text{ LO to GUARD}} \times 100)][\times 5 \text{ for LO voltage}]$$

where $Z_{load \text{ to GUARD}}$ limited to $>100\Omega$

2.3.2 Line Voltage and Frequency Selection

Input voltage selected for Model 296 must match the line voltage available. The line cord connector has provision for changing line voltage, as shown in Figure 2-5. Line voltage only is changed with the line cord connector. Line frequency changes require internal component changes.

To change line frequency to 50Hz operation, 50Hz line frequency kit (ESI Part Number 42537) must be installed. Follow the instructions below to install the kit and change to 50Hz operation.

NOTE: When removing or inserting PC boards, instrument power must be off. Boards must be inserted with components facing front of instrument.

1. Remove crystal Y1 from A/D Converter assembly (board 15 in Figure 4-1, part number 40689). Replace with crystal included in kit (3.2768MHz, part number 24540).

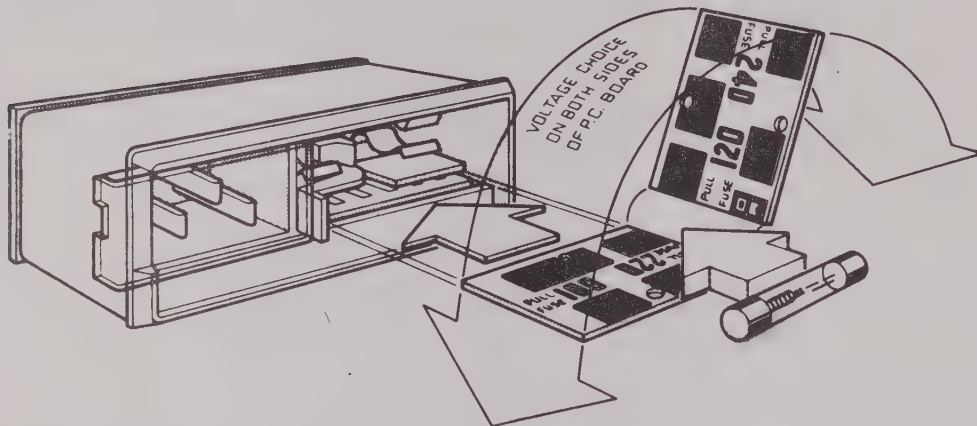
2. Change 120Hz jumper W1 and W3 on Oscillator assembly (board 1 in Figure 4-1, part number 41196) to 100Hz jumpers W2 and W4.

3. Check line voltage setting and change (if necessary) to match available line voltage (see Figure 2-5).

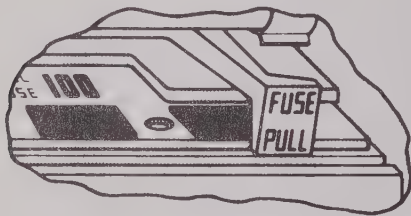
4. Check line fuse. The fuse must be the same value as the line voltage selected.

5. Reinstall both circuit assemblies.

6. Connect an oscilloscope to test point on oscillator assembly shown in Figure 5-12. Sync oscilloscope to line frequency and set sweep at 2ms to 10ms per division. Turn instrument on. Adjust R32 on oscillator assembly for maximum height wave form that remains locked to line frequency.



Operating voltage is shown in module window.



SELECTION OF OPERATING VOLTAGE

1. Open cover door and rotate fuse-pull to left.
2. Select operating voltage by orienting PC board to position desired voltage on top-left side. Push board firmly into module slot.
3. Rotate fuse-pull back into normal position and re-insert fuse in holders, using caution to select correct fuse value.

Figure 2-5. Line Voltage Selection

2.3.3 Input Protection

A circuit prevents damage to the instrument if a charged capacitor is connected to the input terminals. Protection limits can be calculated from the equation:

$$V_{MAX} = \sqrt{\frac{2}{C}}$$

where

V = capacitor voltage in volts
C = capacitor value in farads

The protection circuit in Model 296 allows a maximum energy of 1 joule up to a maximum voltage of 1kV. Table 2-2 below gives examples of maximum voltages for various capacitance values.

1kV	0 to 2 μ F
315V	20 μ F
100V	200 μ F
31V	2mF
10V	20mF
3V	200mF
1V	2F

Table 2-2. Input Protection Limits

When limits are exceeded, the fuse on the rear panel will burn out and must be replaced with a 0.5A 3AG fuse. To prevent possible damage to the instrument use only the proper replacement fuse. (A spare fuse is located adjacent to the bias terminals.)

2.3.4 Resistance Measurement

Resistance should be measured in combination with inductance function rather than capacitance function. When in capacitance mode, a resistor is interpreted as a high loss capacitor and may cause the display to blink. Switching to inductance measurement allows measurement without display blinking.

2.3.5 Deviation Measurement

Two types of deviation measurement are possible with Model 296: deviation as a percent of nominal or absolute deviation from a nominal in units. Percent deviations may range up to $\pm 100\%$ with the nominal value between 1000 and 10,000 counts on a measurement range. Absolute deviations may range up to $\pm$ full scale (measured value of unknown must not exceed full scale value of measurement range, i.e., the measured value must be less than 19,999 counts on any range regardless of its deviation from nominal). Deviation calculations require a small amount of time to complete, so measurement speed is decreased slightly. The additional time required for a measurement is 1ms for absolute deviation, and 5ms for percent deviation.

To measure deviation, a nominal value must first be set. Absolute deviation requires a nominal for the desired function only; percent deviation requires a nominal for both displays when S and Ω are being measured. Nominal values are set as a selected number of counts in the desired display and are not a function of range. Therefore, it is important that the instrument be on the desired range. To set a

nominal value, push NOM VALUE button, enter desired nominal and function (decimal point is controlled by measurement range selected and need not be entered). The nominal will appear in appropriate display window. Push START button to resume measurement. The unit will display absolute deviation from nominal automatically when START button is pushed. For percent deviation, push red button then % key. (D and Q functions display absolute deviation only.) To return to absolute deviation, push red button then Δ key (the Δ indicator will light to show deviation mode is restored). The unit is removed from deviation mode by programming nominal values of 0 for both reactive and loss functions.

To temporarily exit from deviation mode, push SET POINT then START. To return to deviation measurement with the same nominals, push NOM VALUE then START. If the unit had been measuring percent deviation before temporarily exiting, % must be pushed to return to percent deviation measurements.

After exiting deviation measurement mode by pushing SET POINT then START, it is possible to enter limits mode operation by entering desired limits (see Section 2.3.6). The nominals entered for deviation measurement are then used as nominals for % limits operation.

The nominals set can be examined by pushing the NOM VALUE button. The current nominal settings will appear in appropriate display windows.

For example, to set a nominal of 15nF, push the $\uparrow$ or $\downarrow$ button to range to the 20nF range. Press NOM VALUE, digits 1, 5, *F, START. To change to percent deviation, push %. Since the decimal point position is fixed by the range selected, care must be taken to enter the correct sequence of numbers to achieve the desired nominal. Also note that the first digit on each display is a ± 1 display only and cannot show a zero digit input. For example, to set a nominal D value of 0.001, press digits 0, 0, 0, 1. When the first 0 is pressed, the display will not show it since the digit is only capable of displaying a +, - or 1. After pressing the second 0, the display will echo the digits entered. To return to normal operation, press NOM VALUE, 0, *F, NOM VALUE, 0, *D, START.

2.3.6 Limits Operation

Limits mode operation allows unknowns to be sorted into tolerance bands based on set point limits programmed by the operator. There are ten set point limits, 1 through 10, which gives nine bands, numbered 0 through 8, plus one additional limit numbered 10 (See Figure 2-6). Set point limits can be arranged in two methods: nine bands for the reactance of the unknown and one maximum limit for its loss; or nine bands for the loss component of the unknown and one maximum limit for its reactance. The choice between these two arrangements is made when the first set point limit (number 1) is programmed. Limit 1 must always have a value entered.) If a reactance function is

programmed for set point limit one, the nine bands will be allotted for reactance component of unknowns and number 10 limit for loss component. Similarly, if a loss function is programmed for set point limit one, the nine bands are used for loss and number 10 for reactance components. For example, the first arrangement allows capacitors to be sorted into eight tolerance bands (Bands 1 through 8), with one out of tolerance band (Band 0) and one maximum limit on D value (Band 10). The second arrangement allows resistors to be sorted into nine bands with a maximum limit on their inductance. The calculations required for limits operation add 7ms to overall measurement time.

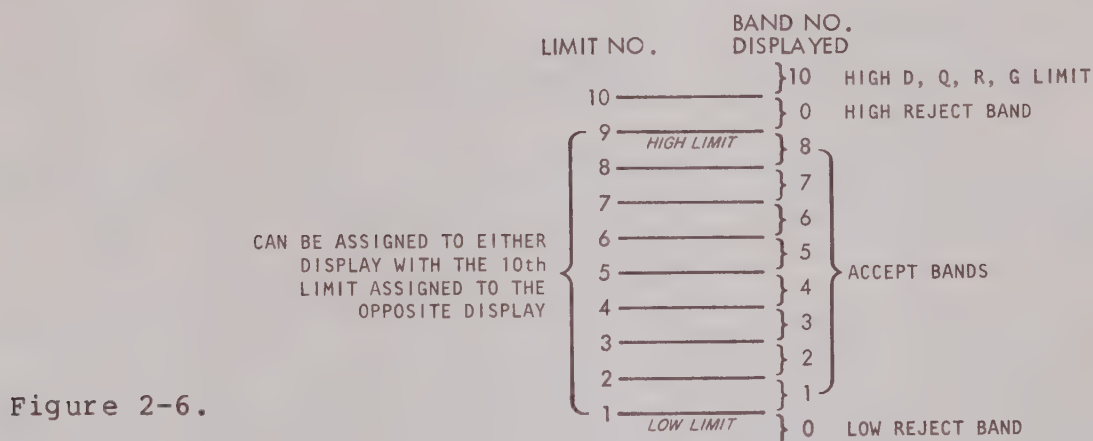


Figure 2-6.

Set point limits may be set in units or percent. They are programmed in ascending order with each limit greater in value than the preceding. A set point limit equal to or less than the previous limit will not be accepted and will cause display blinking. Limits must not exceed the maximum allowable digits for a given function (see Table 1-1). When the instrument is turned on it initializes to the first set point limit (number 1). Each push of the set point button advances the limit number. The following procedures outline the process involved in setting and operating limits.

To set limits in units:

1. Set Model 296 to desired test frequency and range. Push SET POINT button. The left display will show the number of the set point limit being programmed.
2. Enter numerals for desired limit (numerals will appear in right-hand display). Push red button then function for desired limit. The function entered at this step chooses between the two arrangements for the set point limits (nine limits for reactance and one for loss, or nine limits for loss and one for reactance). Entries for the remaining limits (except limit 10) must be of the same function.
3. Push SET POINT again and repeat step 2 to program next set point limit. Repeat until all desired limits are set. At least two limits must be set.

4. To program number 10 limit, enter numerals and function as in other set point limits. Function must be of opposite type (reactance or loss) than the function for the other set point limits programmed. When the function is entered, number 10 limit is set. The number 10 limit is automatically set when its function is entered regardless of set point limit number previously showing.

5. Push *SET POINT then START button to begin measurement. Display will show band number. To show measured value of unknown, push *SET POINT. *SET POINT toggles between showing measured value and band number.

To set percent limits:

For percent limits operation, nominal values must first be set.

1. Set Model 296 to desired test frequency and range. Enter nominal values for reactance and loss components as in deviation measurement description, Section 2.3.5. One will be used for nominal on the nine bands, the other will be used for the maximum limit nominal.

2. Push *% (display will blank). Push SET POINT button. The left display will show the number of the limit being programmed (number 1).

3. Enter numerals for the desired percent limit. Numerals will appear in righthand display. Leading zeros must be entered, but trailing zeros may be left off. For example to enter 17% limit, digits 0, 1, 7 must be pushed. Figure 2-7 shows digit position required for desired percent limits.

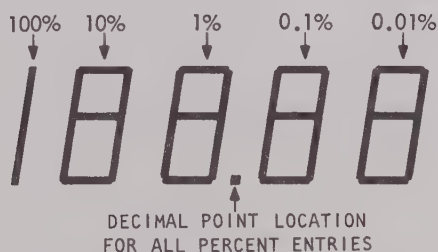


Figure 2-7.

4. Push red button and function. When function button is pushed, the right display will be replaced by a number equal to the nominal deviated by % deviation entered. (The number showing may have a one count error due to round off in the calculation). The function entered for limit 1 is used for limits 1 through 9.

5. Push SET POINT button and repeat steps 3 and 4 for the remaining limits. At least two set point limits must be set.

6. To program number 10 limit, push SET POINT, digit 0, then function desired. Instrument will program set limit 10 to nominal entered for that function in step 1 above.

7. When all set point limits are programmed, push *SET POINT then START to begin measurement.

When operating, the left display shows the proper band number for the unknown component. Band numbers shown indicate the component is greater than the limit of the same number and less than the next higher set point limit. Band 0 indicates the component is either larger than the highest limit or smaller than the smallest limit. Band 10 indicates component has exceeded limit number 10.

To temporarily exit from limits mode into measuring the programmed functions, push *SET POINT. Again pushing *SET POINT toggles back into limits mode. Band sorting information is continuously provided to external handlers, even when the operator toggles out of limits mode, if a handler interface kit is installed.

To completely exit from limits mode, set point limit 1 must be set to zero. If percent limits are set, the instrument must be programmed to absolute limits (by pushing *Δ) before programming set point limit 1 to zero. To return to limits operation re-enter desired set point limits. When power is turned off, all set point limits and nominal values are lost.

To examine set point limits, push SET POINT repeatedly to display limits in ascending order.

Example: Sort 10nF capacitors at 1kHz into ±1%, ±5%, ±10% bands with maximum D of 0.005. Begin by setting proper frequency and range: push HI FREQ, and RANGE, 1, 0, *n, F. Next set nominal values: push NOM VALUE, 1, *F (trailing zeros may be left off, decimal is controlled by range selected). Push NOM VALUE, 0, 0, 0, 5, *D. Now to program set point limits, in percent. Push *. Push SET POINT (until set point limit 1 selected), -, 0, 1(-10%), *F, SET POINT, -, 0, 0, 5(-5%), *F; SET POINT, -, 0, 0, 1(-1%), *F; SET POINT, 0, 0, 1(+1%), *F; SET POINT, 0, 0, 5(+5%), *F; SET POINT, 0, 1(+10%), *F. This sets the capacitance limits, now for D limit. Push SET POINT, 0, *D. Push *SET POINT then START button to begin measurement. Band numbers will appear in the left display. To return to normal measurement, push *Δ, SET POINT (until limit 1 selected), 0, *F, START. This programs set point limit 1 to 0. Instrument remains in deviation mode until nominal values are set to zero.

For parts that do not fall within the acceptable limits it is sometimes desirable to separate the high rejects from the low rejects. This is accomplished by programming set point limit 1 to -15 (this represents -15,000 counts when measuring in absolute limits mode and

-150.00% in percent limits mode) and set point limits 2 for the lowest limit.

Band 1 now represents low rejects with band 0 representing high rejects.

Sometimes it is not desirable to program all set point limits but only a few. (For example, a parts handler used in a 3-band sorting operation may require that set points 6, 7 and 8 be used rather than 1, 2 or 3.) Intermediate bands can be skipped as long as set point No. 1 has a number entered and the limits are set as a group. To insure the low reject band is still 1 less than the lowest limit set:

1. Program set point limit 1 with a value that is more negative than the low limit value.
2. Program all ascending limits with an increasingly positive value until the low limit set point is reached.

Example:

<u>SET POINT</u>	<u>ENTRY</u>	<u>BAND INDICATION</u>
1	-150%	
2	-140%	
3	-130%	Band 3 contains all parts less than -5%
4	- 5%	>4
5	- 1%	>5
6	+ 1%	>6
7	+ 5%	
		Band 0 contains all parts above +5%
10	0%	Band 10 contains all parts whose D exceed the programmed D limit

2.3.7 Settling Time

Settling time may be programmed by the operator. If no settling time is set, the unit defaults to a settling time determined by measurement range and frequency (see Figure 2-8B). Settling times less than default times may cause autoranging to malfunction. To program settling time, push SETTLING TIME button, enter desired settling time in seconds, then push red and SECONDS buttons. Settling time entered must be between 25 milliseconds and 1.2 seconds to nearest 10 milliseconds. For example, to set settling time of 450 milliseconds, push SETTLING TIME, 0, 4, 5, *SECONDS. The display will show .45 seconds as settling time. The unit will accept another digit of resolution when entered, but will truncate it at the 10 millisecond digit.

2.3.8 Measurement Speed

Figure 2-8A shows measurement sequence for various function combinations and measurement types. Measurement and settling times are also shown. Measurement speed of Model 296 is dependent on the type of measurement, settling time, and the functions programmed. Two types of measurement are made: digital averaging and single cycle. Digital averaging is the normal mode of operation for the bridge. It is automatically selected in the continuous measurement mode. Eight measurements of each quantity are taken and the average is computed. The result is then displayed. For faster continuous mode measurements and autoranging, a non-averaged measurement may be selected by test code 0010 (see Section 2.3.9).

Single cycle measurement is the fastest measurement mode. It is useful for remote operation with automatic handlers. A single measurement of each quantity is made and necessary calculations performed. An averaged single cycle measurement can be made using test code 0012 (see Section 2.3.9). This increases measurement time but reduces noise effects.

Settling times for ranges and functions of Model 296 are shown in Figure 2-8B. Settling time is programmable over the range of 25 milliseconds to 1.2 seconds. The effect of settling time changes is shown in the measurement sequence illustrations, Figure 2-8A.

The effect of different function combinations on measurement speed is also shown in the measurement sequence illustrations. Depending on the functions desired, different combinations of quantities must be measured, which may add extra time.

Total measurement time of Model 296 consists of:

1. Settling Time
2. Digital Conversion time
3. Final Calculation Time
4. Special Function Execution Time (Options)
5. GPIB or TTY Data Transfer Period (Options)

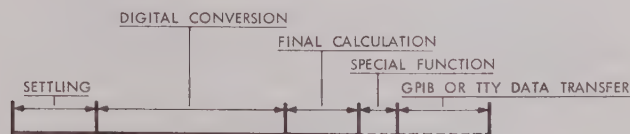
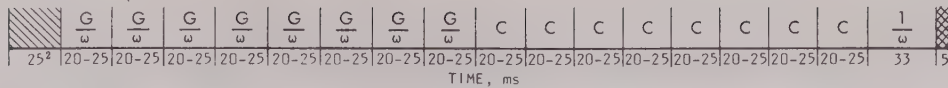
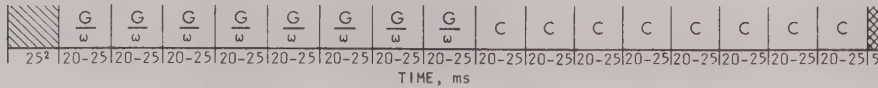
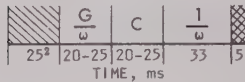
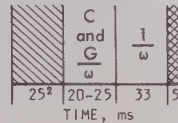


Figure 2-8A.

DIGITAL AVERAGING

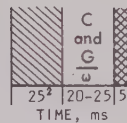
C and Rs or Cp¹*C and D or Q¹*

REMOTE PROGRAMMED SINGLE CYCLE → WITH HIGH SPEED OPTION

C and Rs or Cp¹*C and Rs or Cp¹*

Settling time and autozeroing period

Final calculation period

C and D or Q¹*C and D or Q¹*¹ For Inductance functions, replace G/w with Rs/w and C with L² Dependent on Range, see Settling Time Chart

DC RESISTANCE OPTION MEASUREMENT CYCLES

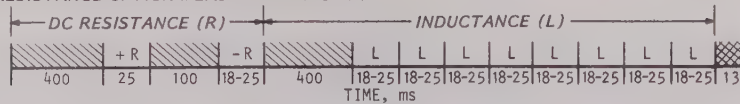


Figure 2-8B.

SETTLING TIME									
C					L				
HI FREQ			LO FREQ			HI FREQ		LO FREQ	
RANGE	SETTLING TIME		RANGE	SETTLING TIME		RANGE	SETTLING TIME STATED ACCURACY ^①	RANGE	SETTLING TIME STATED ACCURACY ^①
	STATED ACCURACY ^①	C ±1% D ±0.005		STATED ACCURACY ^①	C ±1% D ±0.005				
② 200mF	③		② 2F	2000ms ^④	③	1 20μH	100ms	1 200μH	400ms
0 20mF	210ms	⑤	0 200mF	400ms	350ms	2 200μH		2 2000μH	
1 2mF	150ms		1 20mF	200ms	150ms 140ms	3 2mH		3 20mH	
2 200μF	100ms	50ms	2 2000μF	100ms	90ms	4 20mH		4 200mH	
3 20μF	70ms	40ms	3 200μF	120ms	80ms 70ms	5 200mH		5 2000mH	
4 2μF	25ms ^⑥		4 20μF	70ms 25ms ^⑥		6 2H		6 20H	
5 200nF			5 2000nF			7 20H		7 200H	
6 20nF			6 200nF			8 200H		8 2000H	
7 2nF			7 20nF						
8 200pF			8 2000pF						

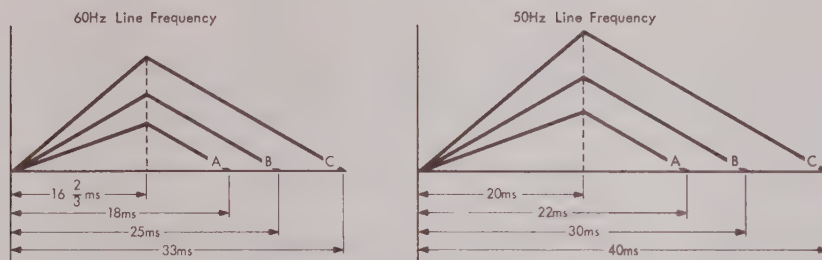
^① Shown are default times, with no settling time programmed. Settling time can be programmed from the front panel or remotely from 25ms to 1.2s. For autoranging, add 100ms to default times.^② Test mode only. See Section 2.3.9 of Model 296 Manual.^③ Not a practical measurement at high frequency.^④ Settling time can be reduced to 1000ms by adding a 1Ω resistor from high drive to guard.^⑤ Not possible - less than stated accuracy.^⑥ 30ms for 50Hz line frequency. A shorted capacitor results in 33ms for 60Hz line frequency and 40ms for 50Hz line frequency.

NOTE: Default times are for initial instrument turn on mode.

Figure 2-8. Model 296 Measurement Speeds

1. **Settling Time** is the time required for the analog voltage representing the unknown to settle to the desired accuracy. Within this period the instrument is autozeroed. Settling times for Stated Accuracy, $\pm 1\%$ and $\pm 3\%$ accuracies are shown in Figure 2-8B.

2. **Digital Conversion Times** of each measurement depend on measured value, line frequency, displayed parameters and operating mode.



A = Full Scale Value B = Zero Value C = Shorted Capacitor Condition

Measurement conversion times are shortest for full scale values and longest for zero or negative values. The maximum conversion time is 25ms for 60Hz line frequency and 30ms for 50Hz line frequency, except for a shorted capacitor or negative value.

The conversion time therefore depends on what percent of full scale the unknown represents. The greater part of full scale, the faster the conversion time. Full scale is 20,000 counts.

The choice of displayed values and operating mode also influences measurement speed. C and D display require only two digital conversion periods while C and G display require an additional period for $1/\omega$ conversion (33ms for 60Hz Line Frequency and 40ms for 50Hz Line Frequency).

Operating mode (single cycle or averaging) also influences measurement speed. The normal mode is averaging. Eight measurements of each parameter are averaged. The single cycle mode is only one measurement of each parameter.

Measurement time can be reduced with the high speed measurement option, ESI Part Number 42445. With this option, the conversion of the loss (G/ω or R/ω) and the reactance (C or L) are executed simultaneously, thus eliminating one conversion period. This option is very useful when interfacing Model 296 with automatic handlers and generally is used in single cycle mode.

3. **Final Calculation Time** is 13ms. This is the time required to calculate the programmed loss function.

4. Special Function Execution Time. Additional time is required to execute special functions.

Absolute deviation mode:	1ms
Percent deviation mode:	5ms
Limits mode:	7ms
Relay closure of handler interface:	1ms
TTL outputs of handler interface:	included within 7ms of limits mode

5. GPIB or TTY Data Transfer Periods. Time is required to output ASCII characters. This time is dependent on the bus system being used and the length of the command and data output character string. Baud rates for the TTY option are detailed in Section 2.4.3.2. Transfer of data on the GPIB is dependent on slowest device connected to bus.

Shorted Capacitors. A shorted capacitor measurement results in an overload condition which requires a longer recovery time than an in-range measurement. When in a high speed measurement mode, this can cause a good part following a shorted part to be rejected. To ensure the good part is not rejected, Model 296 automatically adds an additional 200ms to its settling time if the previous measurement was an overload. This slightly reduces overall throughput, but increases yield.

The extra 200ms settling time can be eliminated by programming clear averaging mode (See Section 2.3.9).

A shorted part also results in 33ms (40ms for 50Hz Line Frequency) digital conversion times for the zero, G/ω , and C measurements. To reduce this extra time, Model 296 will skip the C conversion cycles for the measurement when it senses an overload of G/ω .

2.3.9 Test Mode Functions

Test Mode is a special programming sequence which provides several additional operating functions. Table 2-3 lists these functions and their programming codes. Test Mode functions may be programmed with the interface options just as all other functions. (The keyboard unlock function is not programmable from the front panel, only remotely.)

<u>Code</u>	<u>Function</u>
0000	Unlock front panel (remotely programmable only; keyboard is ignored when locked)
0001	Lock front panel in remote mode
0002	Clear constant current capacitance and constant voltage inductance mode (default)
0003	Set constant current capacitance and constant voltage inductance mode. (Shifts capacitance and inductance ranges up one decade.)
0004	Lock front panel in continuous measurement mode
0005	Set low D mode (special hardware required to implement)
0006	Clear low D mode (default)
0007	Not used
0008	Clear talk only mode (default)
0009	Set talk only mode (printer)
0010	Clear averaging mode (Also eliminates 200ms overload settling time, see Section 2.3.8)
0011	Restore normal mode (default conditions of averaging in continuous and no averaging in single cycle)
0012	Allow averaging on single cycle measurements
0015	Allow averaging of loss component only

Table 2-3. Test Mode Functions and Codes

The front panel lockout feature is controlled by codes 0000 and 0001. This feature allows the controls to be set for the desired measurement operation and then the front panel locked to protect against accidentally changing the settings. After the front panel is locked a remote start signal is required to begin measurement. Since the front panel

is inoperative when locked, it is not possible to unlock the front panel using the keyboard. Three methods can be used to unlock the front panel: turn the unit off then back on, remotely program an unlock command, or close a switch connected to the TTY option front panel unlock feature.

Codes 0002 and 0003 control a special calculated measurement mode. In this mode capacitance is calculated from measured inductance and inductance is calculated from measured capacitance. This extends the range of each function by a factor of ten (to 2F for capacitance, 20,000H for inductance). Capacitors are measured with constant current and inductors with constant voltage in this mode. (Normal measurements are made with constant voltage for capacitance, constant current for inductance). Note that since large capacitors are actually measured as small inductors, it is important to cancel the inductive effects of test fixtures and leads as described in front panel zero adjustment section (Section 2.3.1.4). An alternate method is to measure a known standard and correct the reading using the deviation function described in Section 2.3.5. Since functions in this test mode are calculated, values must be between approximately 1300 and 20,000 counts on a range. In addition to over-range indicated, values below approximately 1300 counts cause under-range overload indications. Autoranging feature may not operate in this mode in all cases. This mode is useful for measuring high loss series capacitances whose dissipation factor is too large to allow calculation of C_s and R_s on the normal function.

Code 0004 programs continuous measurement mode and locks the front panel. The panel may be unlocked by the methods listed for codes 0000 and 0001.

A special low dissipation factor (D) mode is controlled by codes 0005 and 0006. It allows measurement of very low D components with higher accuracy than provided by normal D measurement. Measured full scale D is reduced to 0.1999 when the low D test code is selected. This returns to 1.9999 when the low D function is cleared. The low D test mode should always be used unless the D exceeds 0.2 (20%). Low D circuitry has been included as standard on all Model 296's with serial numbers 83600 and greater. All instruments with serial numbers smaller than 83600 must be modified in order to use the low D feature.

TALK only mode, designed for operation with a printer, is controlled by codes 0008 and 0009. Selection of code 0009 causes Model 296 to output its data to IEEE Bus or TTY immediately when measurement is finished.

Codes 0010, 0011, 0012 and 0015 control measurement averaging operation. In normal mode, Model 296 performs two types of measurement cycles: continuous and single cycle. Normal continuous measurements consist of eight measurements averaged then displayed. Single cycle normally consists of a single measurement. Code 0012 performs one eight-measurement averaged reading cycle each time

measurement is initiated. Code 0010 allows continuous measurements without any averaging and eliminates 200ms overload settling time (see Section 2.3.8). Code 0015 allows averaging of the right display quantities only and operates on continuous and single cycle. Normal averaged continuous measurement or single cycle measurement is restored by code 0011.

To program test mode functions, press T button. Normal test indication (all segments lit) will appear. Push 0 button and displays will blank except for decimal points. Enter code for desired function, then press *SECONDS. Selected function is now programmed. All measurement functions (except autoranging) are programmed and operate as in normal measurement mode.

2.3.10 Operation With Bias

Capacitance Measurements

A dc bias of up to 200V can be applied to the rear panel bias terminals (observe polarity). Bias supply must have low ripple with internal current limit of 100mA and its output impedance must be less than 50mΩ. Leakage current through the unknown can be measured by sampling the current from the bias source to the bias terminals with a low impedance ammeter. If the bias source impedance is not low compared to the unknown, a bypass capacitor whose impedance is 1/5 of the unknown at the operating frequency can be connected across the bias source and ammeter (if used).

WARNING

ELECTRICAL SHOCK HAZARD EXISTS WHEN A BIAS SUPPLY IS CONNECTED TO THIS INSTRUMENT. WHEN AN EXTERNAL BIAS SUPPLY IS ATTACHED, THE BIAS VOLTAGE IS PRESENT ON BOTH FRONT AND REAR PANEL BNC CONNECTORS. USE ONLY BIAS VOLTAGES UP TO 200VDC AND BIAS SUPPLIES CURRENT LIMITED AT 100mA. DO NOT TOUCH, CONNECT OR DISCONNECT THE UNKNOWN COMPONENT OR BNC CABLES WHILE A BIAS VOLTAGE IS APPLIED.

Inductance Unknowns

A dc bias current can be supplied to the bias terminals from a high impedance supply limited to the HI test current listed in Table 1-1. Currents exceeding these values could cause damage to the instrument.

For constant current, the impedance of the supply should be greater than 10 times the unknown impedance and must be bypassed with a capacitor whose ac impedance is 1/5 of the unknown at the operating frequency.

SECTION 3

CIRCUIT DESCRIPTIONS

3.1 INTRODUCTION

The Model 296 Impedance Meter consists of three major sections. The first is the analog system (located on the left half of the instrument) which produces dc voltages proportional to the reactive and resistive part of the unknown being measured. The second (located on the right half of the instrument) is the digital section which consists of the following circuit assemblies:

1. The A/D converter which converts the dc voltages produced by the analog system into digital information.
2. The central processing unit (CPU) which contains the microprocessor, memories, clock, bus drivers and other necessary components and performs the calculations necessary to derive the desired information about the unknown. The CPU also monitors the keyboard for input instructions and provides the signals for control of functions and ranges to all other circuit assemblies.
3. Various plug-in options such as IEEE bus, dc resistance measurement circuit, handler interface kits for band sort indication, high speed option, etc.

The third major section is the operator interface consisting of the keyboard for input and the display circuit assembly for visual output of measured information.

A power supply located in the right rear of the instrument provides the necessary dc operating voltages.

Refer to Figures 3-1 and 3-2 for simplified circuit diagrams.

3.2 THE ANALOG SYSTEM

The analog system is an inverting operational amplifier circuit which has the component being measured (unknown) as the input impedance and a selectable standard resistor (SR located on assembly number 41223) as the feedback impedance. The operational amplifier consists of the Preamp Assembly, Part No. 41225; Sync Int Assembly, Part No. 41194 (used to increase the ac gain); and the Power Amp Assembly, Part No. 41192. The unknown is connected through the Discharge Protection Assembly, Part No. 41875, which protects the instrument from charged unknowns and static discharges. This assembly also contains the

relays used to transfer the unknown connections from the ac bridge to the dc resistance option.

The unknown drive signal path is as follows:

1. Oscillator Assembly, Part No. 41196, produces two selectable frequencies, the lower being locked to the line frequency.
2. The unknown drive level regulator (on assembly number 41225) which holds the measurement circuit excitation at the proper level.
3. The Power Amp Assembly, Part No. 41192.
4. The drive transformer located on the left rear of instrument (on assembly number 41192).
5. Limiting resistors which are switched with the standard resistors to provide stability when measuring high reactance unknowns.

The voltage across the unknown is monitored by the Unknown Gain Assembly (UG), Part No. 40935, which has selectable gains of 1, 10, 100 and 1,000. It amplifies the small voltages across low impedance unknowns. The signal output of UG is labeled V_{unk} . These gains effectively decrease the value of the standard resistor.

The voltage across the standard resistor is monitored by the Standard Gain Assembly (SG) which is identical to the circuit assembly used for the unknown gain. These gains are used to amplify the small voltages across the range resistors when measuring high impedance unknowns and the signal output of SG is labeled V_{std} . These gains effectively increase the value of the standard resistor.

The signals V_{unk} and V_{std} are fed to the signal amplifier and Ref Gen Assembly, Part No. 40943. A switch (labeled Y/Z) selects the voltage to be used as a reference, and the one to be used as the measured signal (explained in Section 3.2.1, Measurement Modes). The measured signal (V_{sig}) is passed through a processing amplifier and is then fed to the phase rectifiers as V_s . The reference signal (V_{ref}) is used two places as follows:

1. V_{ref} is sent to the unknown drive level control where it is rectified and compared to a dc reference voltage. Any error between these signals is used to control a gain stage thus holding the excitation to the measurement system at the proper value.
2. V_{ref} is split into accurate 90° and 0° reference components used by the phase rectifiers to separate the reactive and resistive parts of the unknown signal V_s . These reference generators are adjustable in gain and phase for instrument calibration.

The phase rectifiers produce dc voltages proportional to the amplitude of the signal voltage (V_s) and the phase angle between the signal and the reference. This relationship is:

$$VDC = K V_s \cos(\text{Angle between } V_s \text{ and } V_r)$$

where K is a gain constant.

The four phase rectifiers produce the following dc voltages:

1. V_{sdCQ}

A dc voltage proportional amplitude of the quadrature component (reactance) of the unknown. It is obtained by using the 90° generator as a reference.

2. V_{rdCQ}

A dc voltage proportional to the amplitude of the 90° reference generator. It is obtained by using the 90° generator as a signal and reference.

The measured value of reactance is the ratio of these two signals taken by the A/D converters. By using this ratio method, any change in the measurement system excitation level or frequency, changes both V_{sdCQ} and V_{rdCQ} leaving their ratio unchanged. This provides excellent immunity to changes in drive level and frequency.

3. V_{sdCP}

A dc voltage proportional to the amplitude of the in-phase component (resistive or conductive) derived as in 1 above except using the 0° generator as a reference.

4. V_{rdCP}

A dc voltage proportional to the amplitude of the 0° reference generator derived as in 2 except using the 0° reference generator.

Outputs of the phase rectifiers are fed to four active filters on circuit assembly number 41221. The A/D converter (A/D Lin Assembly, part No. 40702, and A/D Digital Assembly, Part No. 40689) under control of the CPU, first measures the offset voltages, then measures the ratio of selected dc voltages. This provides the CPU with digital information proportional to the value of the selected measurement and offset voltages. The CPU subtracts the voltage offsets from the actual measurement. A second set of A/D converters (available as a

High Speed Option, Part No. 42445) decreases the total measurement time by allowing the measurement of two quantities at the same time. The measured quantities are as follows:

$$\text{Offset Voltages} = \frac{\text{ZERO}}{\text{VrdcQ}}$$

$$\text{Cp or Ls} = K \frac{\text{VsdcQ}}{\text{VrdcQ}}$$

$$\frac{\text{Gp}}{\omega} \text{ or } \frac{\text{Rs}}{\omega} = K \frac{\text{VsdcP}}{\text{VrdcQ}}$$

$$\frac{1}{\omega} = K \frac{\text{VrdcP}}{\text{VrdcQ}}$$

3.2.1 Measurement Modes

The analog system is operated in an admittance (Y) or impedance (Z) mode.

The Y mode measures parallel susceptance and conductance by applying a constant voltage across the unknown. This voltage is amplified by gain channel UG where it is called V_{unk} . V_{unk} is further processed to become the reference voltage. The voltage across the unknown produces a current proportional to the parallel conductance and susceptance of the unknown. This current is converted to a signal voltage by allowing it to flow through the standard resistor (SR) and is amplified by selectable gain channel SG. This voltage (V_{std}) is then a measure of the unknown admittance and is:

$$V_{\text{std}} = (I_{\text{unk}}) (\text{SR}) (\text{SG}) = (V_{\text{unk}}) (\text{SR}) (\text{SG}/\text{UG}) (Y_{\text{unk}}) = (V_{\text{unk}}) (\text{SR}) (\text{SG}/\text{UG}) (\text{Gp} + j\text{Bp})$$

$$\text{where Gp} = \text{Parallel Conductance of unknown} = \frac{1}{\text{Parallel Resistance}}$$

$$\text{where Gp} = \text{Parallel Susceptance of unknown} = \frac{1}{\text{Parallel Reactance}}$$

UG = Unknown Gain SG = Standard Gain

The phase rectifiers produce dc voltages proportional to Gp and Bp. The actual measured values are parallel capacitance (Cp) derived from Bp, and Gp/ω derived from Gp by the A/D converter using ratio techniques.

The Z mode measures series reactance and resistance by applying constant voltage to the standard resistor which produces a constant

current. This current is allowed to flow through the unknown producing a signal which is a measure of the unknown impedance and is:

$$V_{unk} = (I_{ref}) (Z_{unk}) (UG) = (V_{std}/R_{std}) (Z_{unk}) (UG/SG) \\ = (V_{std}/R_s) (UG/SG) (R_s + jX_s)$$

The phase rectifiers produce dc voltages proportional to R_s and X_s . The actual measured values are series inductance (L_s) derived from X_s , and R_s/ω derived from R_s by the A/D converter using ratio techniques.

Quantities Measured and Calculated

Table 3-1 lists quantities that are measured and those calculated by the microprocessor.

	ADMITTANCE (Y BRIDGE) FUNCTION (CONSTANT VOLTAGE ACROSS UNKNOWN)			IMPEDANCE (Z BRIDGE) FUNCTION (CONSTANT CURRENT THRU UNKNOWN)		
	LEFT DISPLAY	RIGHT DISPLAY	OTHERS	LEFT DISPLAY	RIGHT DISPLAY	OTHERS
MEASURED QUANTITIES	C_p	G_p / ω	$1/\omega$	L_s	R_s / ω	$1/\omega$
CALCULATED QUANTITIES (Calculated from Measured Quantities Above)	$C_s^* = C_p (1 + D^2)$	$D = \frac{G_p}{\omega C_p}$ $Q = \frac{\omega C_p}{G_p}$ $R_s = \frac{D}{\omega C_s}$ $G_p = \frac{G_p}{\omega} \times \omega$		$L_p^* = L_s (1 + D^2)$	$D = \frac{R_s}{\omega L_s}$ $Q = \frac{\omega L_s}{R_s}$ $G_p = \frac{D}{\omega L_p}$ $R_s = \frac{R_s}{\omega} \times \omega$	
TEST MODE CALCULATED QUANTITIES (See Section 2.3.9)	$L_p = \frac{-1}{\omega^2 C_p}$ $L_s^* = \frac{-1}{\omega^2 C_s}$	$G_p = \frac{G_p}{\omega} \times \omega$ $D = \frac{G_p}{\omega C_p}$ $Q = \frac{\omega C_p}{G_p}$		$C_s = \frac{-1}{\omega^2 L_s}$ $C_p^* = \frac{-1}{\omega^2 L_p}$	$R_s = \frac{R_s}{\omega} \times \omega$ $D = \frac{R_s}{\omega L_s}$ $Q = \frac{\omega L_s}{R_s}$	

*NOT CALCULATED WHEN $D > 1.9999$ OR $Q < 0.5$

Table 3-1

3.3 THE DIGITAL SYSTEM

3.3.1 The CPU

The CPU Circuit Assembly, Part no. 41491, has complete control of all functions of the instrument and does all the calculations required to arrive at the desired measured quantity. It communicates with the instrument via an 8 bit bidirectional data bus. The CPU selects the circuit it needs to communicate with via a 16 bit address bus. Desired instrument functions such as range, frequency, etc., are selected on the appropriate circuit assembly by solid state switches or relays. Digital information to set these functions is stored by the CPU into temporary memory, called latches, located on the display board and other circuit assemblies as follows:

1. The CPU selects the proper latch via the address line.
2. The CPU outputs the proper bit pattern to set the desired function on the 8 bit data bus.
3. The CPU then sends a strobe pulse which stores this bit pattern into the selected latch.

3.3.2 The Display Circuit Assembly, Part No. 41329

This assembly contains the following circuits:

1. Temporary memory (latches) for the displays, units and their multipliers, keyboard decoding and instrument functions and ranges.
2. The displays with their units and multipliers.
3. A 1.6 millisecond oscillator interrupt used to multiplex the displays and keyboard.
4. The C, G, L and R ZERO ADJUSTMENT circuit.

3.3.2.1 Displays and Keyboard

The right and left displays and the keyboard are multiplexed at a 1.6 millisecond rate. The total time to multiplex through the display is then 10 milliseconds with each digit being energized for 16% of the total time. This 10 millisecond total time is also used for the

settling time increments. Multiplexing is accomplished by the interrupt oscillator sending a pulse to the interrupt line of the CPU. Upon receiving this pulse, the CPU performs the following operations:

1. Fetches from memory the bit pattern for the next digit, unit and multiplier for the right and left display and stores it in the appropriate latch.
2. Transfers energizing current to the next display digits.
3. Examines the keyboard to determine if a key has been pressed.

If a key has been pressed, the CPU performs a debounce routine by requiring that the key be down for five successive total multiplexing times (50 milliseconds) before it will accept it.

3.3.2.2 C Zero, G Zero and L Zero, R Zero Circuits

C Zero, G Zero

The signal voltage from unknown high sense is buffered and applied to an inverting unity gain amplifier on the display PC board. This amplifier has two potentiometers spanning its input and output (the C zero and G zero front panel trimmers) which send signals variable in amplitude and phase to the preamp and level regulator board. These signals are applied to the low side of the unknown through a resistor (G Zero) and a capacitor (C Zero) which is variable to increase or decrease the C zeroing range. This allows the addition or subtraction of capacitance or conductance to the measured unknown to compensate for open-circuit lead or test fixture offsets.

L Zero, R Zero

The signal current from unknown low drive is sensed and applied to an inverting unity gain amplifier on the display PC board. This amplifier also has two potentiometers spanning its input and output (the L zero and R zero front panel trimmers) and sends its signals, variable in amplitude and phase, to the unknown GAIN PC board. These signals are mixed with the voltage across the unknown being measured through a capacitor (L Zero) and a resistor (R Zero). This allows the addition or subtraction of inductance or resistance to the measured unknown to compensate for short-circuit lead or test fixture offsets. L and R zero circuitry affects high frequency measurements only. Early instruments did not have this feature.

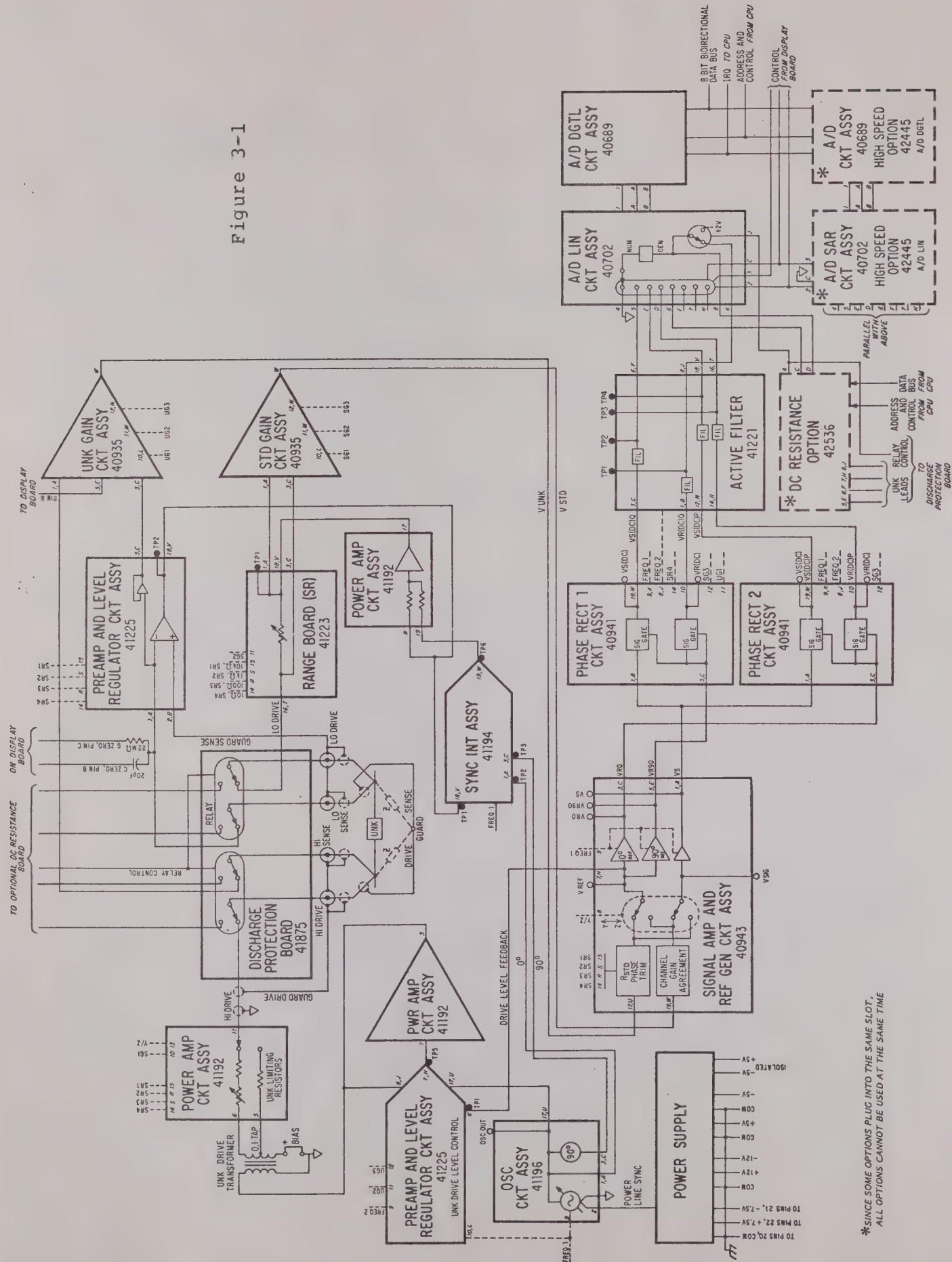
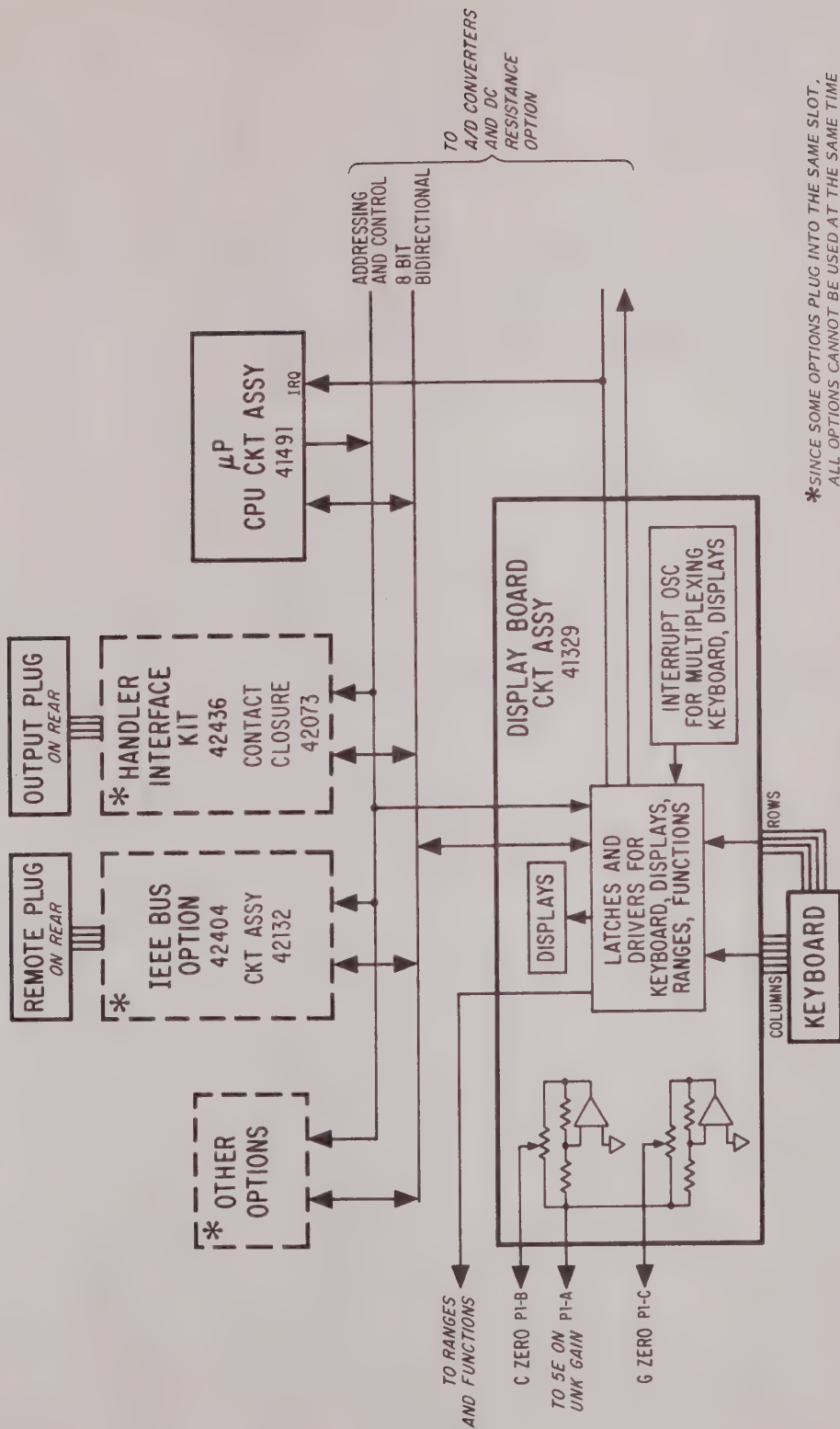


Figure 3-1

*SINCE SOME OPTIONS PLUG INTO THE SAME SLOT, ALL OPTIONS CANNOT BE USED AT THE SAME TIME.



*SINCE SOME OPTIONS PLUG INTO THE SAME SLOT,
ALL OPTIONS CANNOT BE USED AT THE SAME TIME

Figure 3-2.



WARNING

SERVICING INFORMATION IN THE FOLLOWING SECTIONS IS INTENDED FOR USE BY QUALIFIED SERVICE PERSONNEL ONLY. TO AVOID PERSONAL INJURY DO NOT PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THE OPERATING INSTRUCTIONS IN THIS MANUAL UNLESS QUALIFIED TO DO SO.

Before undertaking any troubleshooting or maintenance procedure carefully read the applicable section in this manual and note all WARNINGS and CAUTIONS.

SECTION 4

CALIBRATION AND MAINTENANCE

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

CAUTION

WHEN PERFORMING ANY CALIBRATION OR MAINTENANCE OPERATION, DO NOT REMOVE OR REPLACE CIRCUIT BOARDS WHILE THE POWER IS TURNED ON. FAILURE TO TURN POWER OFF MAY RESULT IN ELECTRIC SHOCK OR DAMAGE TO THE INSTRUMENT.

4.1 CALIBRATION

The calibration procedure is divided into three sections:

Section 4.1.1 (3 month intervals) is operational amplifier voltage, offset, and zero capacitance and conductance adjustment. Calibration should not be needed for long periods of time because of the high quality operational amplifiers used in this instrument. Calibration should, however, be checked occasionally to account for normal component aging.

Section 4.1.2 (6 month intervals) compensates for operational amplifier and passive component aging and should be checked periodically. Section 4.1.1 should always precede Section 4.1.2 during calibration.

Section 4.1.3 is a factory calibration which need be used only if a circuit assembly has been replaced.

Refer to Figure 4-1 for board, test point, and trimmer locations.

Required Equipment

DC Voltmeter with 1mV resolution

100Ω, 1kΩ and 10MΩ resistance standards (100Ω and 10MΩ for DC resistance option only)

1nF to 1μF low D standard capacitor (value known to ±0.01%, D known to 0.0002) (Use 0.01μF - GR)

Frequency Counter

Oscilloscope

4.1.1 Zero Adjustments

1. Turn instrument power on.

2. Set instrument to the 1μF range.

Push RANGE  1  μ  F  START

3. Separate the test leads for minimum capacitance (approximately 4 inches).

4. Adjust trimmer 1 on board 5 for zero on left display.

5. Adjust trimmer 1 on board 7 for zero on right display.

6. Set instrument to low frequency. Push   LO FREQ

7. Adjust trimmer 2 on board 5 for zero on left display.

8. Adjust trimmer 2 on board 7 for zero on right display.

9. Set instrument to high frequency. Push   VOLTAGE
10. Set to autorange. Push  
11. Adjust front panel G control for zero on the right display.
12. Adjust front panel C control for zero on the left display.
13. Connect the standard capacitor.
14. Set instrument to measure D. Push  
15. Push  until the left display reads one-tenth of full scale.

NOTE: It is not abnormal for the D reading to fluctuate in 6 count jumps around the measured value. To correct this condition see Step 21.

16. Adjust trimmer 1 on board 7 for known D value. If the D reading is fluctuating, adjust trimmer until the display varies equally above and below the known D value.
17. Set instrument to low frequency. Push   FREQ
18. Push  to maintain one-tenth of full scale in left display.
19. Adjust trimmer 2 on board 7 for known D value.

NOTE: D accuracy is $\left(\frac{20,000}{\text{counts of C}} \right) \times 0.3$

20. Set instrument to high frequency. Push  FREQ
21. Set to low D measurement mode.
Push        

NOTE: In this mode the D accuracy is improved by a factor of 10 to:

$$\left(\frac{20,000}{\text{counts of C}} \right) \times 0.03$$

The maximum D measurement allowed is reduced from 1.9999 to 0.2.

22. Push  until the left display reads one-tenth of full scale.
23. Adjust trimmer 1 on board 18 for known D value ± 2 counts.
24. Set instrument to low frequency. Push  
25. Push  to maintain one-tenth full scale reading in left display.
26. Adjust trimmer 2 on board 7 for known D value ± 2 counts.
27. Return instrument to normal D measurement mode.
Push        
28. Set to high frequency. Push 

4.1.2 Accuracy Adjustments

4.1.2.1 A/D Converter

1. Disconnect and separate the test leads for minimum capacitance (approximately 4 inches).
2. Connect the DC voltmeter between TP 1 on board 16 and ground.
3. Adjust trimmer 3 on board 16 for zero ± 1 mV.

4. Repeat for board 17 if optional A/D Converter is in place. (At the time of installation perform the calibration described in Section A.7.4.)

4.1.2.2 HI Frequency Capacitance

(THIS ADJ. AFFECTS HF INDUCTANCE READINGS. MAY HAVE TO OVERADJUST CAP. READINGS IN ORDER FOR AUTO THE INDUCTANCE READINGS TO (MATCH THE SPEC.)

5. Set instrument to autorange. Push   (AUTO)
6. Connect the standard capacitor.
7. Adjust trimmer 4 on board 6 for known C value ± 2 counts. If value cannot be reached, adjust trimmer 2 on board 16 (without high speed option installed) or trimmer 2 on board 17 (with high speed option installed) until the known value is reached.
8. Adjust trimmer 7 on board 6 for known D value ± 2 counts.

4.1.2.3 LO Frequency Capacitance

9. Set instrument to low frequency. Push   LO FREQ
10. Adjust trimmer 2 on board 6 for known C value ± 2 counts.
11. Adjust trimmer 5 on board 6 for known D value ± 2 counts.

★ 4.1.2.4 HI Frequency Resistance

12. Set instrument to high frequency. Push  HI FREQ
13. Set to measure conductance. Push   S
14. Connect the $1k\Omega$ low reactance standard resistor. (ECI-SR1)

15. Set instrument to range hold. Push  
16. For the next step, alternate the measurement function between F and S, and H and Ω . Push     then    
17. Adjust trimmer 3 on board 6 for equal counts from zero on the left display.

NOTE: One reading is negative and one is positive.

18. Set instrument to measure H and Ω . Push    
19. Adjust trimmer 8 on board 6 for known R value ± 2 counts.

4.1.2.5 LO Frequency Resistance

20. Set instrument to low frequency. Push  
21. For the next step, alternate the measurement function between F and S and H and Ω . Push     then    
22. Adjust trimmer 1 on board 6 for equal counts from zero in the left display.

NOTE: One reading is negative and one is positive.

23. Set instrument to measure H and Ω . Push    
24. Adjust trimmer 6 on board 6 for known R value ± 2 counts.

4.1.2.6 DC Resistance Option (when installed)

25. Set instrument to the DC resistance function. Push  RANGE DC OHMS 
26. Connect the $1k\Omega$ standard resistor.
*26a IF 1k RANGE CANNOT BE ADJUSTED SELECT R43 STARTING AT 1meg UP.
SET R14 CENTER OF RANGE*
27. Adjust trimmer ~~R14~~^{R11} on board 14 for known R value.
(A)
28. Connect the 100Ω standard resistor.
29. Adjust trimmer ~~2~~^{R11} on board 14 for known R value.
(B)
30. Connect the $10M\Omega$ standard resistor.
31. Adjust trimmer ~~3~~^{R45} on board 14 for known R value.
(C)

4.1.3 Calibration (factory)

NOTE: The following calibration adjustments are normally made at the factory and need only be made when a circuit assembly is replaced. Set trimmer 3 on boards 5 and 7 to maximum counter-clockwise position.

Addition Equipment Required

Decade Capacitor -- with know dissipation factor. Values to $1\mu F$ are required. Polystyrene Capacitors are preferred -- assume a dissipation factor of 0.0002. Values to $1\mu F$ are required.

10Ω , 1%, Low Reactance Resistor

4.1.3.1 Oscillator Adjustment

1. Connect a frequency counter to the OSC OUT test point on board number 1.
2. Set instrument to high frequency. Push  HI FREQ
3. Adjust trimmer 1 on board 1 for 1kHz, ± 1 Hz.
4. Set to low frequency. Push   LO FREQ
5. Connect an oscilloscope to the TST test point on board 1.
6. Synchronize the oscilloscope to line frequency.
7. Adjust trimmer 2 on board 1 for maximum signal on scope.

4.1.3.2 A/D Converter Adjustment

NOTE: Trimmer 1 on the A/D converter board is not used in this instrument and should be left in the middle of its trim range.

8. Adjust trimmer 2 on board 16 (and board 17 when High Speed Option is installed) to the middle of its trim range.
9. Set instrument to high frequency. Push  HI FREQ
10. Set to high voltage. Push  HI VOLTAGE
11. Set to autorange. Push  AUTO 
12. Set to measure Fp and S. Push  F   S 
13. Connect the voltmeter (set to VDC) to TP1 on board 16.

14. Adjust trimmer 3 on board 16 for 0VDC, $\pm 0.1V$.
15. Repeat for board 17 if optional A/D Converter is in place. (At the time of installation perform the calibration described in Section A.7.4.)

4.1.3.3 Synchronous Integrator Adjustment

16. Set instrument to high frequency. Push  HI FREQ
17. Set to measure Fp and S. Push    
18. Set to high voltage. Push  HI VOLTAGE
19. Set to autorange. Push  
20. Separate test leads for minimum capacitance (approximately 4 inches).
21. Connect oscilloscope to TP4 on board 2.
22. Adjust trimmer 1 on board 2 to minimize the fundamental waveform. (Some 2nd harmonic may remain.)
23. Connect oscilloscope to TP5 on board 2.
24. Adjust trimmer 2 on board 2 to minimize the fundamental waveform. (Some 2nd harmonic may remain.)
25. Connect oscilloscope to TP1 on board 2.
26. Adjust trimmers 3 and 4 on board 2 to minimize the fundamental waveform. (Some 2nd harmonic may remain.)
27. Repeat steps 21 through 26 for best results.

28. Set instrument to low frequency. Push  

29. Check steps 16 through 26 for the indicated results.

NOTE: If the waveform at TP1 (step 25) exceeds 50mV peak-to-peak, consult the troubleshooting procedure in this manual.

4.1.3.4 Preamplifier and Level Regulator Adjustment

30. Set instrument to high frequency. Push 

31. Set to measure Fp and S. Push    

32. Set to high voltage. Push 

33. Set to autorange. Push  

34. Separate test leads for minimum capacitance (approximately 4 inches).

35. Connect the voltmeter (set to VAC) to TP5 on board 4.

36. Adjust trimmer 2 on board 3 for 1V RMS, $\pm 0.001V$.

37. Set instrument to low frequency. Push  

38. Check steps 30 through 36 for the indicated results.

NOTE: If the waveform at TP5 is not 1VRMS $\pm 2mV$, consult the troubleshooting procedure in this manual.

4.1.3.5 Zero Adjustments

39. Set instrument to 1 μ F range.

Push

RANGE



1



μ

F



START

40. Set to high frequency. Push  HI FREQ

41. Set to high voltage. Push  HI VOLTAGE

42. Separate test leads for minimum capacitance (approximately 4 inches).

43. Adjust trimmer 1 on board 5 for zero on left display.

44. Adjust trimmer 1 on board 7 for zero on right display.

45. Set to low frequency. Push   LO FREQ

46. Adjust trimmer 2 on board 5 for zero on left display.

47. Adjust trimmer 2 on board 7 for zero on right display.

48. Set instrument to high frequency. Push  HI FREQ

49. Set to autorange. Push  AUTO 

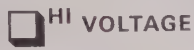
50. Adjust the front panel C and G zero trimmers until the left and right displays read zero.

51. Set to low voltage. Push   LO VOLTAGE

52. Adjust trimmer 1 on board 3 for zero on left display.

53. Repeat steps 50 through 52 for best results.

4.1.3.6 Signal Amp and Reference Generator Adjustments

54. Set instrument to measure Fp and D. Push    
55. Set to high frequency. Push 
56. Set to high voltage. Push 
57. Set to autorange. Push  
58. Connect the decade capacitor to the test leads.
59. Set the decade capacitor to 1.6nF.
60. For step 61, alternate the measurement function between Hs and Fp. Push   then  
61. Adjust trimmer 7 on board 6 for equal readings on right display (ignore sign).
62. Set instrument to Fp and D. Push   
63. Adjust trimmer E on board 6 for known value of D ± 2 counts.
64. Set instrument to low frequency. Push  
65. Set decade capacitor to 15nF.
66. For step 65 alternate between Fp and Hs.
Push   then  
67. Adjust trimmer 5 on board 6 for equal readings in the right display (ignore sign).
68. Set instrument to Fp and D. Push   

69. Adjust trimmer 9 on board 6 for known value of $D \pm 2$ counts.
70. Set to high frequency. Push  HI FREQ
71. Set to measure F_p and D . Push    
72. Set decade capacitor to 10nF .
73. Adjust trimmer D on board 6 for known value of D on the right display.
74. Set decade capacitor to $0.1\mu\text{F}$.
75. Adjust trimmer C on board 6 for known value of D on the right display.
76. Set decade capacitor to $1\mu\text{F}$.
77. Adjust trimmer B on board 6 for known D on the right display.
78. Connect $1\text{k}\Omega$ low reactance standard resistor to the test leads.
79. Set to range hold. Push  
80. For steps 78 through 83, alternate the measurement function between H_s and Ω , and F_p and S .
Push     then    
81. Adjust trimmer 10 on board 6 for equal right display readings ($\Omega=S$).
82. Adjust trimmer 8 on board 6 until the right display reads the same as the known resistance value ± 2 counts ($H-\Omega$ mode).
83. Adjust trimmer 3 on board 6 for equal counts from zero on the left display.

84. Set instrument to low frequency. Push  
85. Adjust trimmer 1 on board 6 for equal counts on the left display.
86. Set instrument to measure Fp and S. Push    
87. Adjust trimmer 6 on board 6 until the right display reads the same as the known resistance value.
88. Connect the 1nF standard capacitor.
89. Set instrument to high frequency. Push 
90. Set instrument to measure D (dissipation). Push  
91. Set to autorange. Push  
92. Adjust trimmer 4 on board 6 for known C value. If value cannot be reached, adjust trimmer 2 on board 16 (without High Speed Option installed) or trimmer 2 on board 17 (with High Speed Option installed) until the known value is reached.
93. Adjust trimmer 7 on board 6 for known value of D.
94. Set to low frequency. Push  
95. Adjust trimmer 2 on board 6 for known C value.
96. Adjust trimmer 5 on board 6 for known D value.
97. Repeat steps 78 through 96 for best results.
98. For steps 99 through 101, alternate the measurement function between Hs and Ω , and FP and S.

Push     then    

99. Connect a 10Ω , 1% low reactance resistor to the test leads. *Hi Freq*
100. Adjust trimmer A on board 6 for equal counts from zero on the left display.
101. Adjust trimmer 3 on board 5 for zero on the left display.
102. Repeat steps 100 and 101 for best results.

4.1.3.7 Gain Channel Adjustments

103. Set instrument to high frequency. Push  HI FREQ
104. Set to high voltage. Push  HI VOLTAGE
105. Set to autorange. Push   AUTO
106. Set to measure Fp and D. Push   F   D
107. Connect a 100pF polystyrene capacitor.
108. Adjust trimmer 2 on board 8 for known D value.
109. Set instrument to low voltage. Push   LO VOLTAGE
110. Connect a 1nF standard capacitor to the test leads.
111. Adjust trimmer 2 on board 4 for known D value.
112. Connect a 100pF polystyrene capacitor to the test leads.
113. Adjust trimmer 3 on board 8 for known D value.
114. Connect oscilloscope to the rightmost test point on board 8.

115. Set instrument to 10mF range.

Push RANGE  1 0  m F  START

116. Connect oscilloscope to the rightmost test point on board 4.

117. Adjust trimmer 1 on board 4 for minimum DC component on the scope.

118. Adjust trimmer 1 on board 8 for minimum DC component on the scope.

4.1.3.8 Optional Short Circuit Zero Adjustment

119. Set instrument to measure H_s and Ω . Push  H  

120. Set to autorange. Push  AUTO 

121. Set to low frequency. Push  LO FREQ

122. Set to high voltage. Push  HI VOLTAGE

123. Connect a 10m Ω , 1% resistor to the test leads.

124. Record the front panel readings.

125. Set to high frequency. Push  HI FREQ

126. Adjust the L and R front panel adjustments for the same readings as recorded for low frequency operation.

4.1.3.9 Active Filter--Low D Option Adjustment

127. Set instrument to measure Fp and D. Push    

128. Connect standard capacitor (1nF).

129. Push  until the left display reads 1000 counts.

130. Adjust trimmer 1 on board 7 for known D value.

NOTE: D accuracy fluctuates in approximately 6 count jumps. This is shown by the equation:

$$D \text{ Accuracy} = \left(\frac{20,000}{\text{Counts of C}} \right) \times 0.3$$

131. Program low D operation.

Push        SECONDS   START

NOTE: In this mode the D accuracy is improved by a factor of 10 to:

$$D \text{ Accuracy} = \left(\frac{20,000}{\text{Counts of C}} \right) \times 0.03$$

132. Adjust trimmer 1 on board 18 for known D value ± 2 counts.

133. Set instrument to low frequency. Push   FREQ

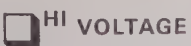
134. Push  to maintain 1000 counts of C displayed.

135. Adjust trimmer 2 on board 7 for known D value ± 2 counts.

4.1.3.10 Full Scale "D" Adjustment with High Speed Option Installed

136. Set instrument to high frequency. Push 

137. Set to Fp and D. Push    

138. Set to high voltage. Push 

139. Connect a "D" standard with a D not to exceed 0.1999.

NOTE: A "D" standard can be constructed by connecting a good decade capacitor to the unknown terminals. Set the Model 296 to its $1\mu\text{F}$ range. Set the decade capacitor to a value that reads 10,000, ± 5 counts on the left display. Connect a $1\text{k}\Omega$, $\pm 0.05\%$ resistor in parallel with the decade capacitor. This will provide a D reading of 0.1592.

140. Adjust trimmer 2 on board 16 for known D value.

4.2 MAINTENANCE

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

This section of the manual contains maintenance information for use in preventive maintenance, corrective maintenance, and troubleshooting of the Model 296.

4.2.1 Preventive Maintenance

WARNING

REMOVAL OF INSTRUMENT COVERS MAY CONSTITUTE AN ELECTRICAL HAZARD AND SHOULD BE ACCOMPLISHED BY QUALIFIED SERVICE PERSONNEL ONLY.

Preventive maintenance performed on a regular basis will improve the reliability of this instrument. It may include cleaning, visual inspection, or even monitoring the operating environment.

4.2.1.1 Cleaning

CAUTION

AVOID THE USE OF CHEMICAL CLEANING AGENTS WHICH MIGHT DAMAGE THE PLASTICS USED IN THIS UNIT. DO NOT APPLY ANY SOLVENT CONTAINING KETONES, ESTERS, OR HALOGENATED HYDROCARBONS. TO CLEAN, USE ONLY WATER SOLUBLE DETERGENTS, ETHYL, METHYL, OR ISOPROPYL ALCOHOL.

Exterior. Loose dust may be removed with a soft cloth or a dry brush. Water and mild detergent may be used; however, abrasive cleaners should not be used.

Interior. Use low-velocity compressed air to blow off the accumulated dust. Hardened dirt can be removed with a cotton-tipped swab, soft, dry cloth, or a cloth dampened with a mild detergent and water.

4.2.1.2 Visual Inspection

This instrument should be inspected occasionally for such defects as broken connections, improperly seated semiconductors, damaged circuit boards, and heat-damaged parts.

The corrective procedure for most visible defects is obvious. If heat damaged components are found, particular care must be taken. Overheating usually indicates other trouble may be present in the instrument. It is important that the cause of overheating be corrected to prevent recurrence of the damage.

The air filter, located on the rear panel (see Figure 4-2), should be visually inspected every 90 days. It should be cleaned or replaced whenever necessary. To clean or replace:

1. Turn instrument power off.
2. Slide filter out from behind the fan finger guard.
3. Clean filter by shaking or blowing air across it.
4. Reinstall by sliding filter into place behind the finger guard.

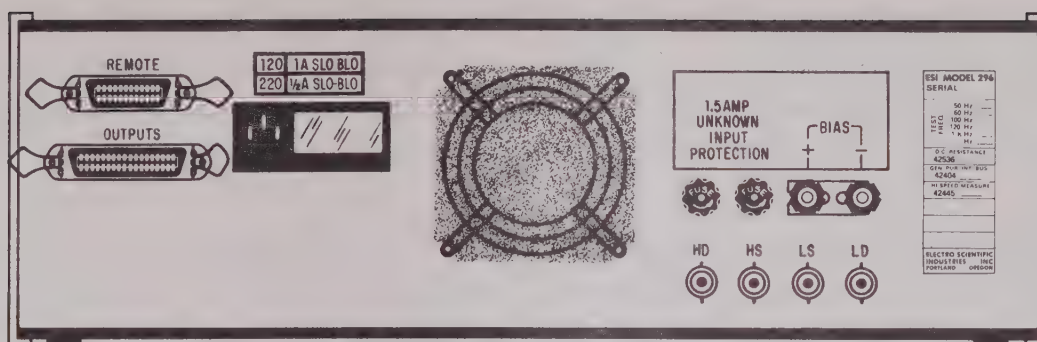


Figure 4-2.

4.2.2 Troubleshooting

The following troubleshooting information is provided to augment other sections of this manual. The Circuit Description and Part Lists and Schematic Diagrams sections should be used to full advantage. Section 3 in this manual gives circuit description information while, Section 5 contains the part lists and schematic diagrams.

4.2.2.1 Troubleshooting Aids

Schematic Diagrams. Schematic diagrams are provided on foldout pages in Section 5. The electrical value and circuit numbers of each component are shown on the diagrams. Power supply voltages are also shown.

Circuit-Board Illustrations. Illustrations of circuit boards are shown along with the schematic diagrams. Each board-mounted electrical component is identified by its circuit number.

Test Point Locations. Test point locations have been indicated on both the schematic diagrams and the circuit-board illustrations.

Component Color Code. Colored stripes or dots on resistors and capacitors signify electrical values, tolerances, etc., according to the EIA standard color code. Components not color-coded usually have the value printed on the body.

Multi-pin Connector Identification. Multi-pin connectors are soldered to the circuit boards. Connector pins 1 and A are indexed with a number 1 and letter A etched on the circuit board. Each connector is identified by a P number and can be located by using the circuit board illustrations in Section 5 of this manual. P numbers shown on the illustration correspond to the J numbers on the schematic diagrams.

4.3 TROUBLESHOOTING PROCEDURE

This troubleshooting procedure checks the simple trouble sources before proceeding with more extensive troubleshooting. The first few checks ensure proper instrument setup and test lead connection. If the trouble is not located by these checks, the remaining steps aid in isolating the problem to a particular PC board. When the defective PC board is located, it can either be replaced and sent to the factory for repair or more extensive troubleshooting can proceed until the faulty component is found.

4.3.1 Instrument Preparation

1. Turn instrument OFF.
2. Remove the top cover.
3. Perform a visual check of the instrument. Many problems can be located by visual indications such as unsoldered connections, incorrect connections, damaged circuit boards, damaged components, or components bent over and touching.

4. Remove the test leads and all other external connections from the 296 except the power cord.
5. Make sure the shorting strap is connected between the + and - bias terminals.
6. Check the line fuse, line voltage setting, and line frequency setting. See Section 2.3.2 in this manual.

4.3.2 Problem Isolation

This portion of the troubleshooting procedure isolates a problem to either the power supply, the options installed, or the standard Model 296. Before proceeding, the troubleshooter should read and become familiar with the circuit and measurement descriptions and the block diagram located in Section 3 of this manual. For PC board and test point locations refer to Figure 4-1. Troubleshooting will follow the flow indicated in Figure 4-3.

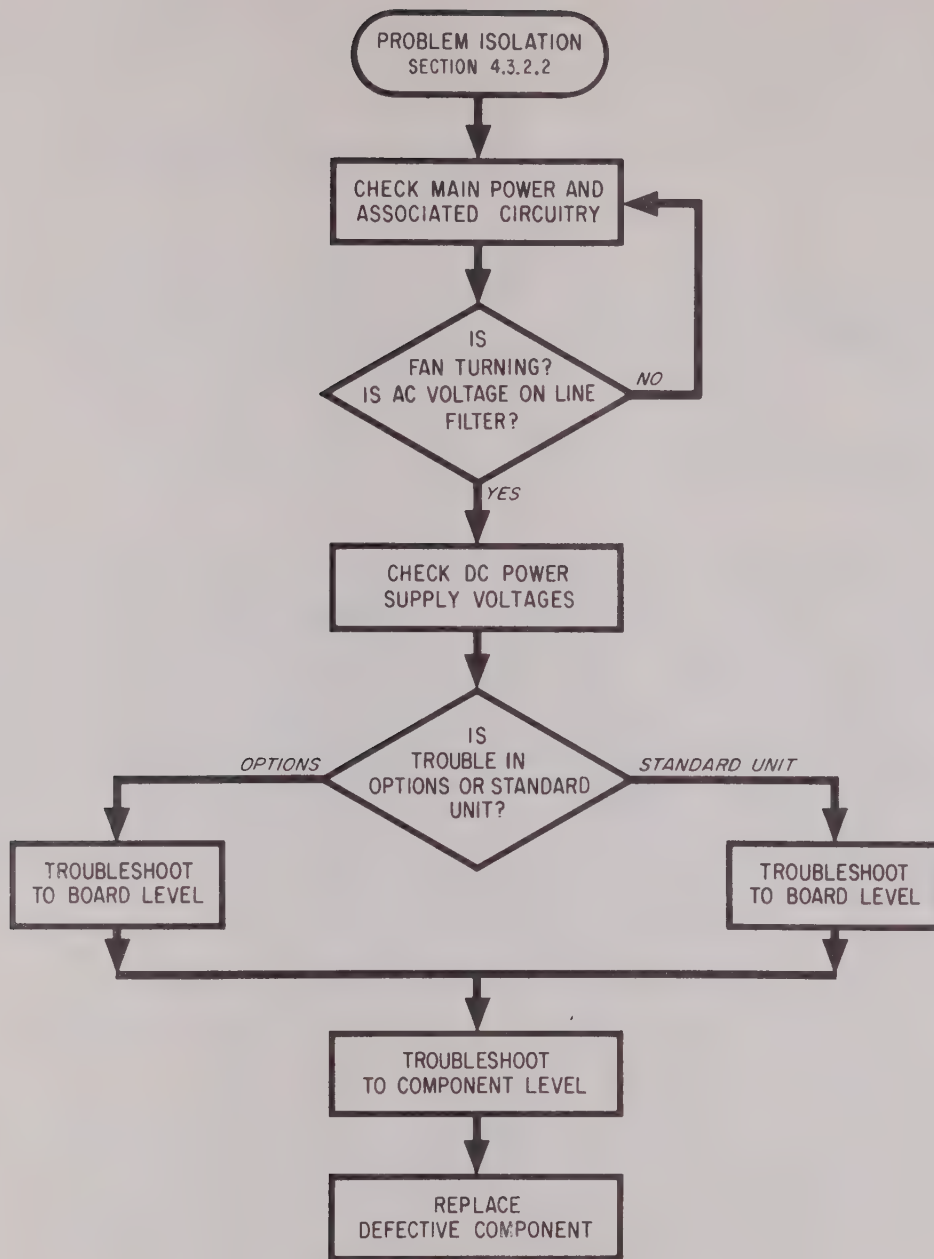


Figure 4-3. Basic Troubleshooting Flow Chart

1. Turn instrument ON.
2. Check to see if the rear panel fan is operating.
3. Check the AC voltage to the line filter. Connect a voltmeter between pin B and ground (see Figure 4-4).

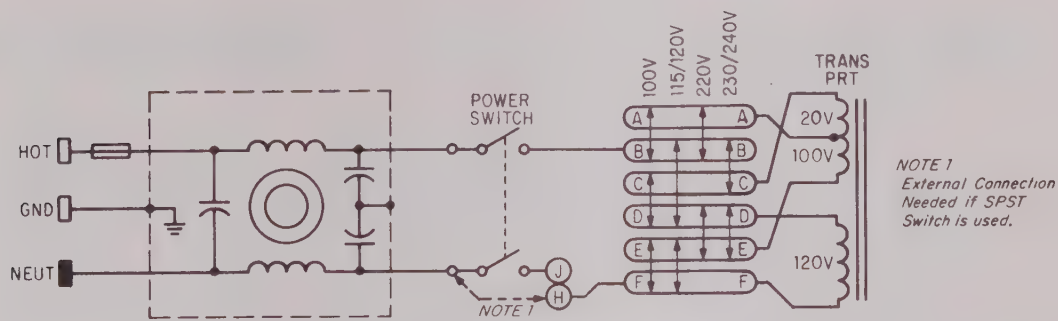


Figure 4-4. Line Filter

4. Check the power supply voltage levels (see Figure 4-5).

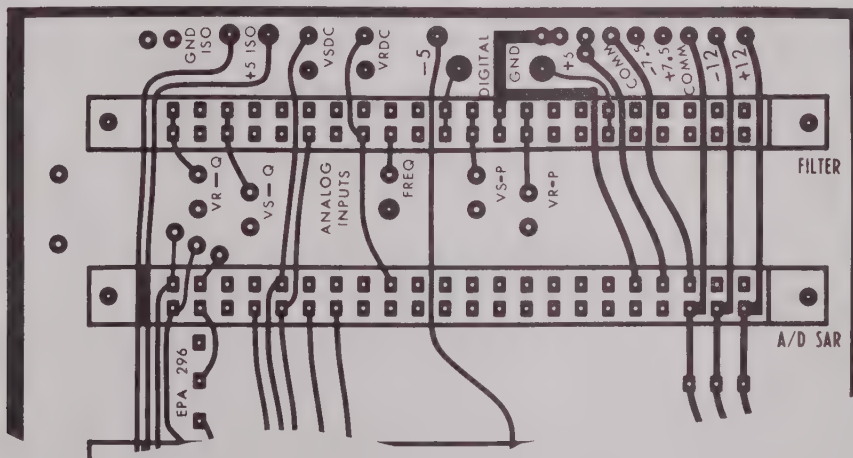


Figure 4-5. Right-hand Motherboard

5. Remove all option PC boards from the Model 296 mainframe.



WHEN PERFORMING ANY CALIBRATION OR MAINTENANCE OPERATION, DO NOT REMOVE OR REPLACE CIRCUIT BOARDS WHILE THE POWER IS TURNED ON. FAILURE TO TURN POWER OFF MAY RESULT IN ELECTRIC SHOCK AND/OR DAMAGE TO THE INSTRUMENT.

- A. If the problem has disappeared, go to the Options Troubleshooting section of this procedure.
- B. If the problem still exists, go to the Standard Model 296 Troubleshooting section of this procedure.

4.3.3 Standard Model 296 Troubleshooting

The Standard Model 296 Troubleshooting procedure isolates a malfunction to a particular PC board. Once the problem board is found more extensive troubleshooting can begin or the board can be replaced and sent to the factory for repair. Figure 4-6 Standard Troubleshooting Summary is a flow indicator for the procedure that follows.

Push	Left Display	Right Display
RANGE      	----- pF _p	+-.----- μ S
 H 	----- H _p	+-.----- μ S
 Ω 	----- H _S	+-.----- M Ω
 F 	----- F _S	+-.----- M Ω
 % 	----- %	+-.----- M Ω 7.
 D 	----- %	+-.----- D
 Q 	----- %	+-.----- Q
NOM VALUE  1  F 	+ 100.00 Δ p F _S	+ 000.0 Q Δ
NOM VALUE  0  F 	+ 00.00 p F _S	+ 000.0 Q
 S 	----- pF _p	+-.----- μ S
	-.----- nF _p	+-.----- μ S
	-.----- nF _p	+-.----- μ S
	----- nF _p	+-.----- mS
	-.----- μ F _p	+-.----- mS
	----- μ F _p	+-.----- mS
	----- μ F _p	+-.----- S
	-.----- mF _p	+-.----- S
	-.----- mF _p	+-.----- S
 Ω 	-.----- mF _S	+-.----- m Ω
	-.----- m F _S	+-.----- m Ω
	----- μ F _S	+-.----- Ω
	-.----- μ F _S	+-.----- Ω
	-.----- μ F _S	+-.----- Ω
	----- n F _S	+-.----- k Ω
	-.----- nF _S	+-.----- k Ω
	-.----- nF _S	+-.----- k Ω
	----- pF _S	+-.----- M Ω
 Ω LO FREQ	----- p F _S LF	+-.----- M Ω
 Ω LO VOLTAGE	----- p F _p LF	+-.----- M Ω LV
	+1.8.8.8.8. LF	+1.8.8.8.8. LV

NOTE: - = blank display

Table 4-1. Display Indicator Check

Connector P1 Pin Numbers		9	10	11	12	14	15	K	L	M	N	R	S
Signal Name		Freq	UG1	UG3	SG2	SR4	SR1	Z/Y	UG2	SG1	SG3	SR3	SR2
Push	RANGE	H	L	L	L	L	L	H	L	H	L	L	L
	VOLTAGE	H	H	L	H	L	L	H	L	H	L	L	L
	VOLTAGE	H	L	L	L	L	L	H	L	L	L	L	L
		H	L	L	L	L	H	H	L	L	L	L	L
		H	L	L	L	L	L	H	L	L	L	L	H
		H	L	L	L	L	L	H	L	L	H	H	L
		H	L	L	L	H	L	H	L	L	L	L	L
		H	H	L	L	H	L	H	L	L	L	L	L
		H	H	L	L	H	L	H	H	L	L	L	L
		H	H	L	L	H	L	H	H	L	L	L	L
FREQ		H	H	L	L	H	L	L	H	L	L	L	L

NOTE: H = +7.5VDC

Table 4-2. Measurement (relay) Control Signal Check

- Connect the test leads to the 296. See Section 2.3.1.3 for proper connection.
- Connect a 150nF capacitor to the test leads.
- Set the instrument to measure F_p and S. Push
- Set to high frequency. Push FREQ
- Set to high voltage. Push VOLTAGE

NOTE: If the instrument is malfunctioning it may not autorange to the proper range. When this happens, manually set the instrument to the 150nF range by pushing:

RANGE 1 5 0

High Drive Regulating Circuitry

1. Check the Oscillator's high frequency output signal.

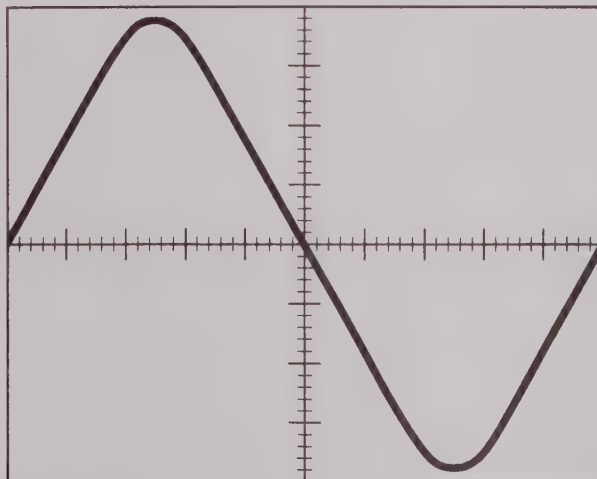
Set oscilloscope controls:

Time per Division = 0.1ms
Volts per Division = 1V
Trigger = Int/Auto

Connect scope probe: (board 1, TP OSC OUT)



Proper signal:



- A. If no signal is present or the signal is greatly distorted, replace the faulty Oscillator PC board.
- B. If the signal is as shown, go to step 2.

2. Check the Oscillator's low frequency output signal.

Push   LO FREQ

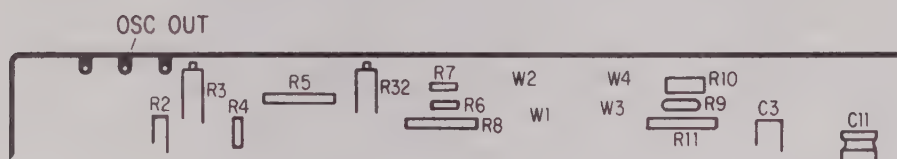
Set oscilloscope controls:

Time per Division = 1ms

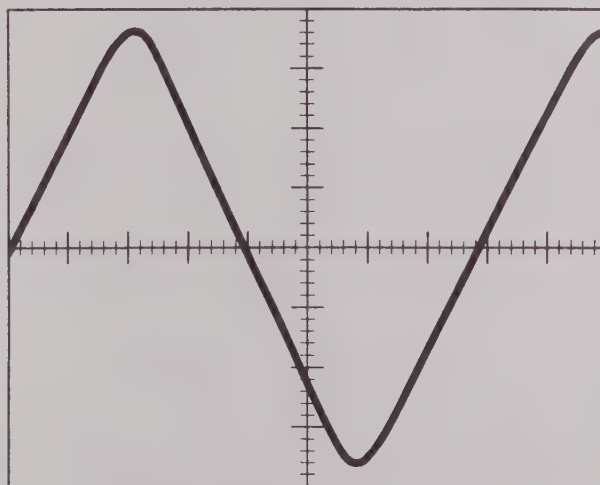
Time per Division = 1V

Trigger = Line/Auto

Connect scope probe: (board 1 TP OSC OUT)



Proper signal:



- A. If the signal is not present or is distorted, replace the faulty Oscillator PC board.
- B. If the signal is as shown, return to high frequency then go to step 3.

3. Check the Unknown Gain output signal.

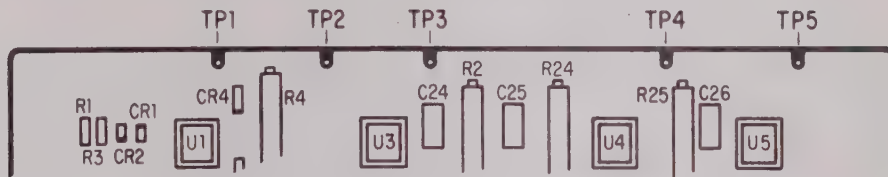
Set oscilloscope controls:

Time per Division = 0.1ms

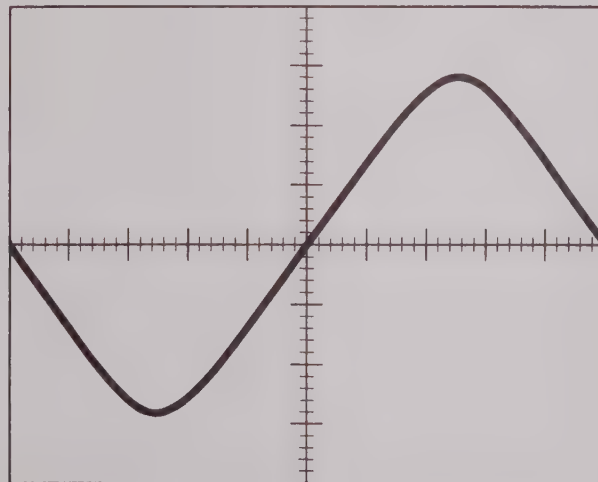
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 4, TP 5)



Proper signal:



- A. If the proper signal is present, go to step 9.
- B. If the signal is larger than shown (can be an overload signal), go to step 8.
- C. If no signal is present, go to step 4.

4. Check the Unknown Gain for presence of signal. Check board 4, TPs, 1,2,3, and 4
 - A. If a signal is present (same signal as step 3 or larger) at one or more test points, replace the faulty Unknown Gain PC board.
 - B. If no signal is present, go to step 5.

5. Check the Unknown High Drive test signal.

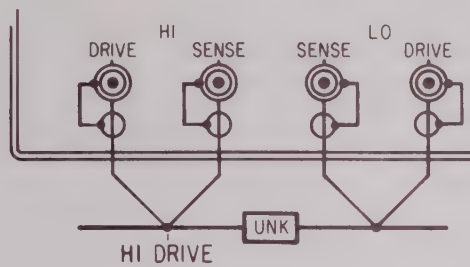
Set oscilloscope controls:

Time per Division = 0.1ms

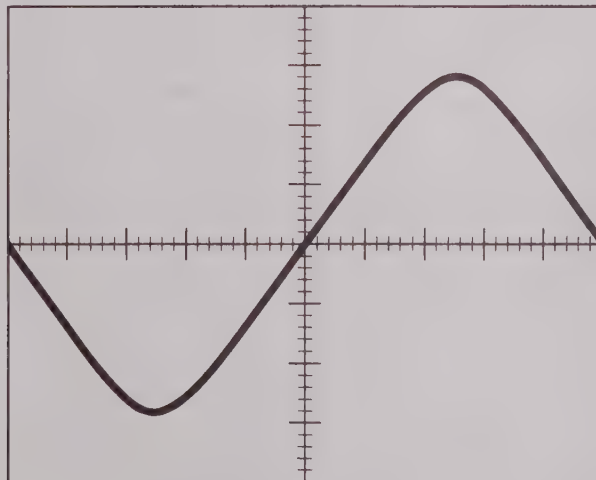
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (HI Drive test lead)



Proper signal:



A. If a signal is present (as shown or larger), replace the faulty test lead set or the Discharge Protection PC board.

B. If no signal is present, go to step 6.

6. Check the Preamp and Level Regulator.

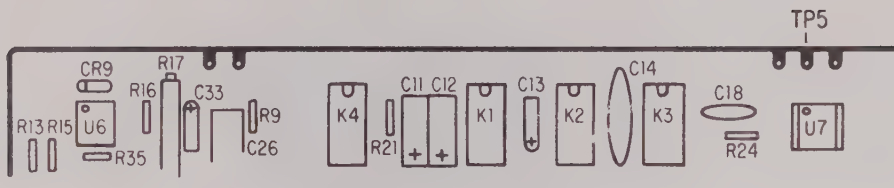
Set oscilloscope controls:

Time per Division = 0.1ms

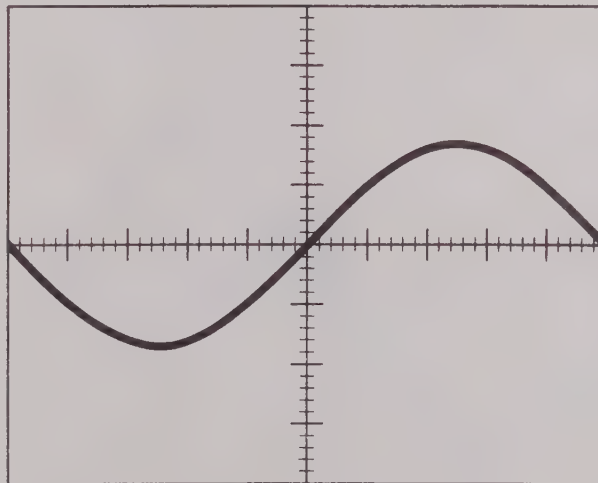
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 3, TP 5)



Proper signal:



- A. If a signal (as shown or larger) is present, replace the faulty Power Amplifier PC board or the Unknown Drive Transformer.
- B. If no signal is present, go to step 7.

7. Check the Preamp and Level Regulator.

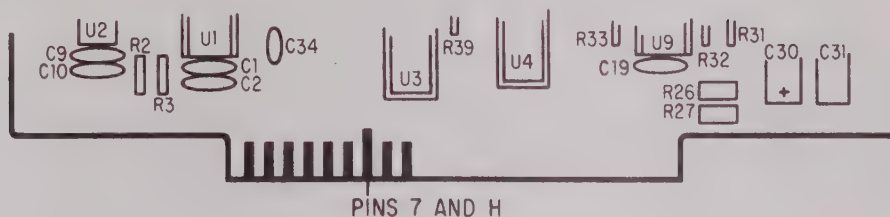
Set oscilloscope controls:

Time per Division = 0.1ms

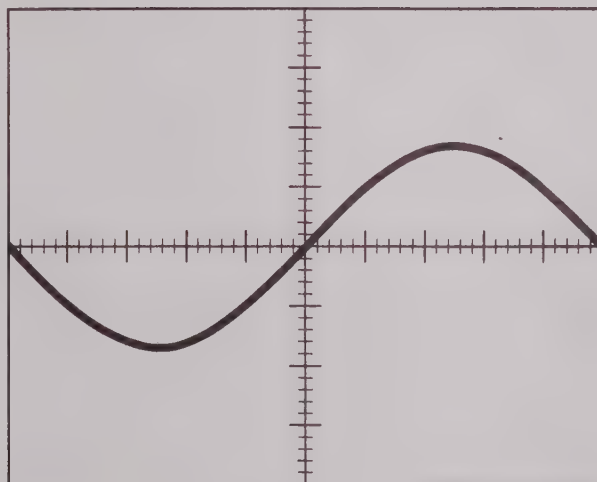
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 3, output pins 7 and H)



Proper signal:



- A. If a signal (as shown or larger) is present, replace the faulty Power Amplifier PC board or the Unknown Drive Transformer.
- B. If no signal is present, replace the faulty Preamp and Level Regulator PC board.

8. Check the Preamp and Level Regulator (TP1)

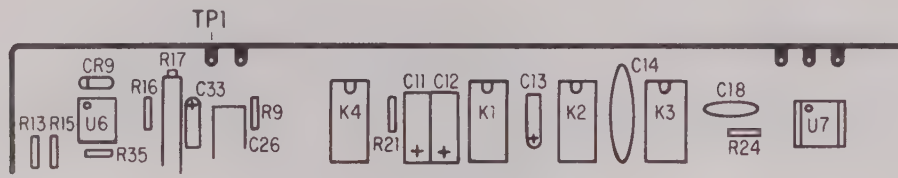
Set oscilloscope controls:

Time per Division = 0.1ms

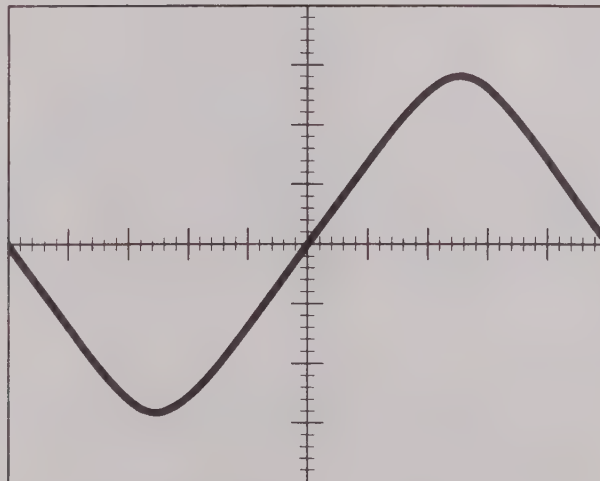
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 3, TP 1)



Proper signal:



- A. If no signal is present, replace the faulty Signal Amp and Reference Generator PC board.
- B. If the signal is present but not correct, replace the faulty Preamp and Level Regulator PC board.

Low Drive Regulating Circuitry

9. Check the Standard Gain output signal.

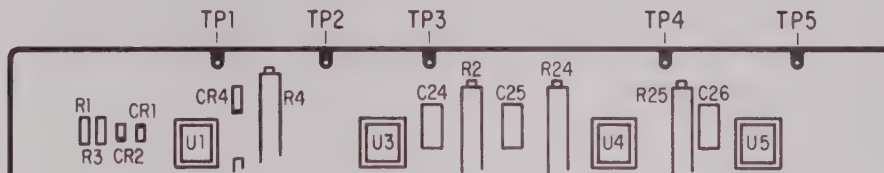
Set oscilloscope controls:

Time per Division = 0.1ms

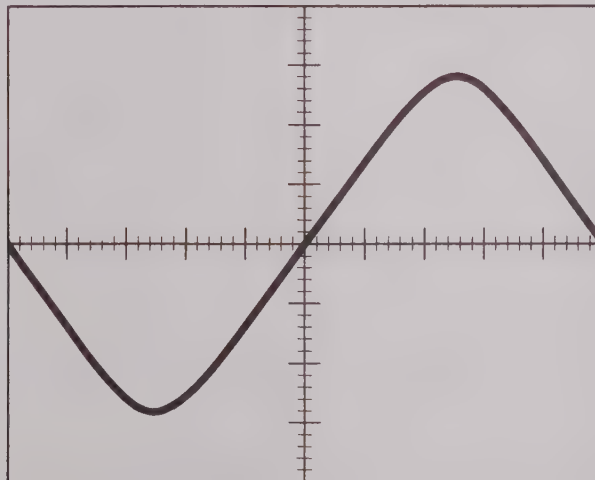
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 8, TP 5)



Proper signal:



- A. If the signal is as shown, go to step 14.
- B. If no signal is present or the signal is not correct, go to the step 10.

10. Check the Standard Gain for the presence of a signal. Check board 8, TP's 1,2,3, and 4.

A. If the signal is present (same signal as step 9) at one or more test points, replace the faulty Standard Gain PC board.

B. If no signal is present or it is not as shown, go to step 11.

11. Remove the Synchronous Integrater PC board from the 296.



WHEN PERFORMING ANY CALIBRATION OR MAINTENANCE OPERATION, DO NOT REMOVE OR REPLACE CIRCUIT BOARDS WHILE THE POWER IS TURNED ON. FAILURE TO TURN POWER OFF MAY RESULT IN ELECTRIC SHOCK AND/OR DAMAGE TO THE INSTRUMENT.

A. If the problem disappears, replace the faulty Synchronous Integrater PC board.

B. If the problem still exists, go to step 12.

12. Check the Range board.

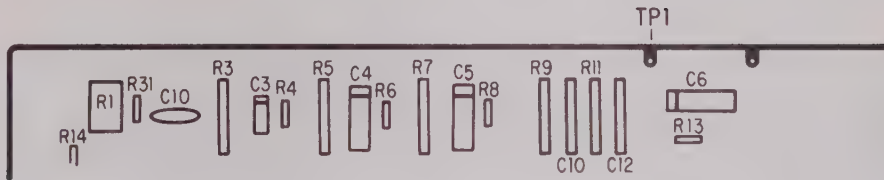
Set oscilloscope controls:

Time per Division = 0.1ms

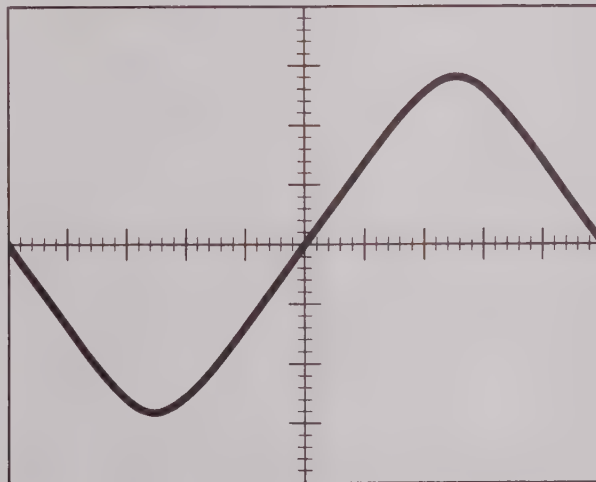
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 9, TP 1)



Proper signal:



- A. If the signal is as shown, replace the faulty Standard Gain PC board.
- B. If no signal is present or it is not correct, go to step 13.

13. Check the Preamp and Level Regulator.

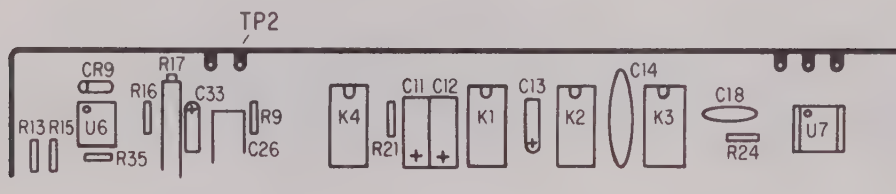
Set oscilloscope controls:

Time per Division = 0.1ms

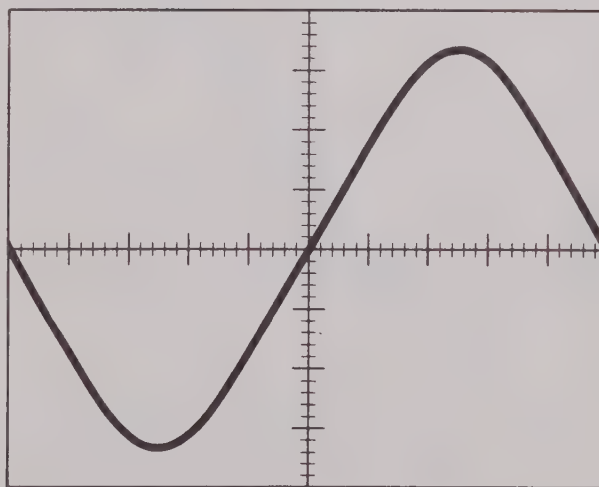
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 3, TP 2)



Proper signal:



- A. If the signal is as shown, replace the faulty Power Amplifier and/or Range PC boards.
- B. If no signal is present or it is not correct, replace the faulty Preamp and Level Regulator PC board.

Signal Processing Circuitry

14. Check the Signal Amplifier and Reference Generator.

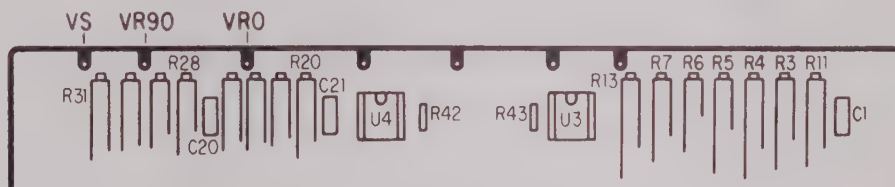
Set oscilloscope controls:

Time per Division = 0.1ms

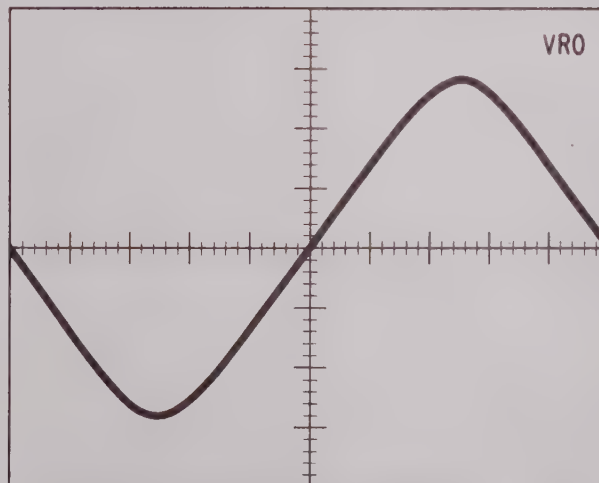
Volts per Division = 0.5V

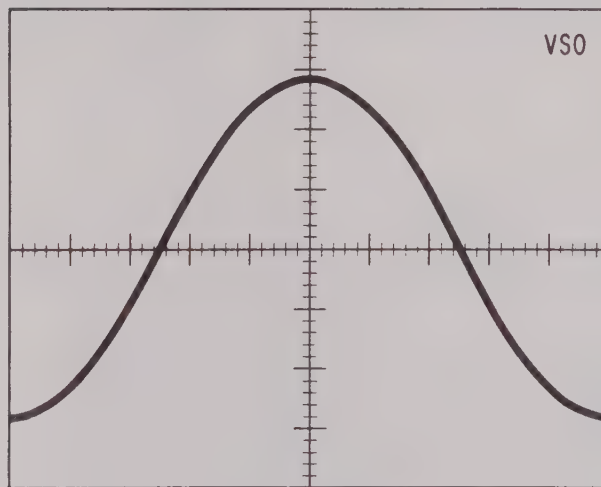
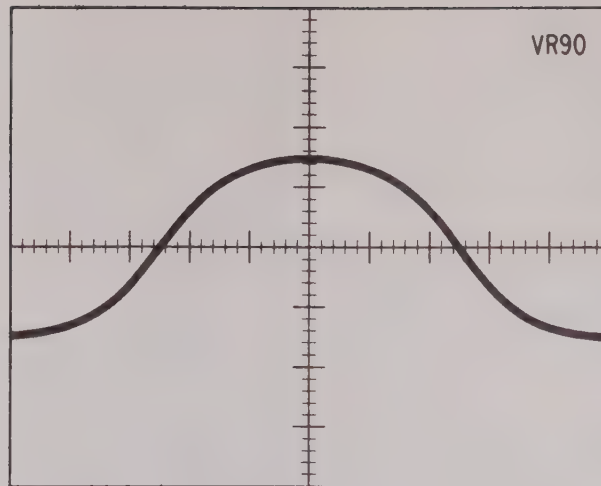
Trigger = Ext/Auto -- trigger on board 6, TP VR0

Connect scope probe: (board 6, TP's VR0, VR90, and VS)



Proper signal:





- A. If one or more signals are not as shown, replace the faulty Signal Amp and Reference Generator PC board.
- B. If the signals are as shown, go to step 15.

15. Check the Phase Rectifier (board 5) output.

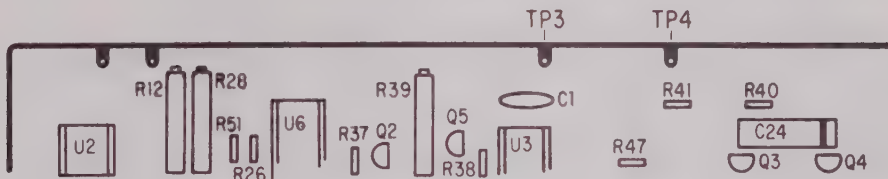
Set oscilloscope controls:

Time per Division = 0.1ms

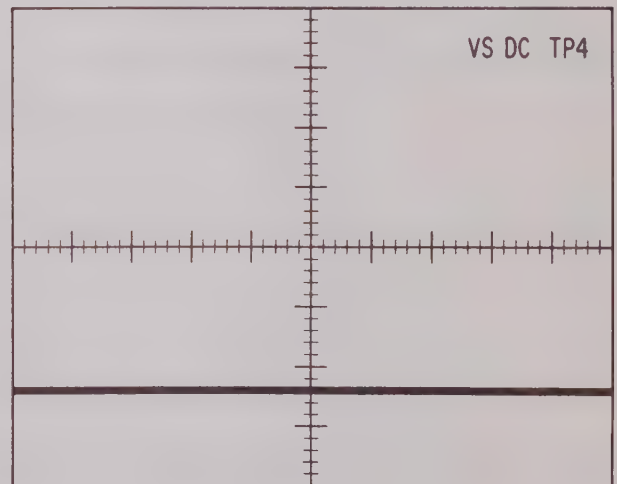
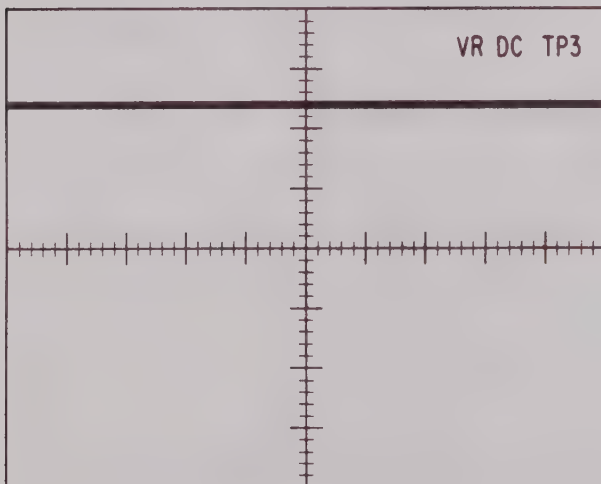
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 5, TP's VRDC [TP3] and VSDC [TP4])



Proper signal:



- A. If the DC signals are not as shown, replace the faulty Phase Rectifier PC board.
- B. If the signals are as shown, go to step 16.

16. Check the Phase Rectifier (board 7) output.

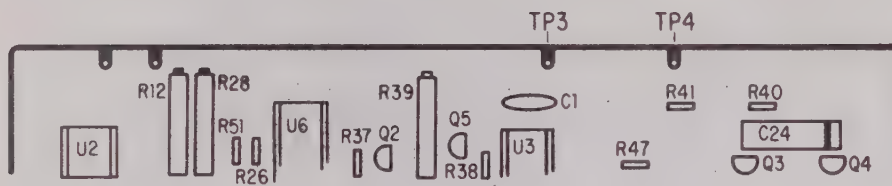
Set oscilloscope controls:

Time per Division = 0.1ms

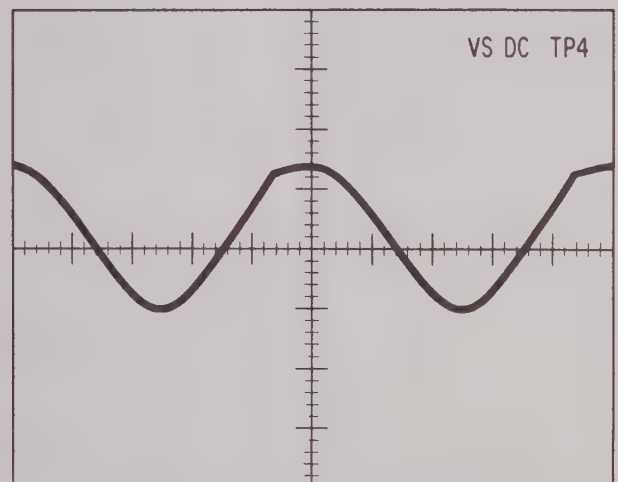
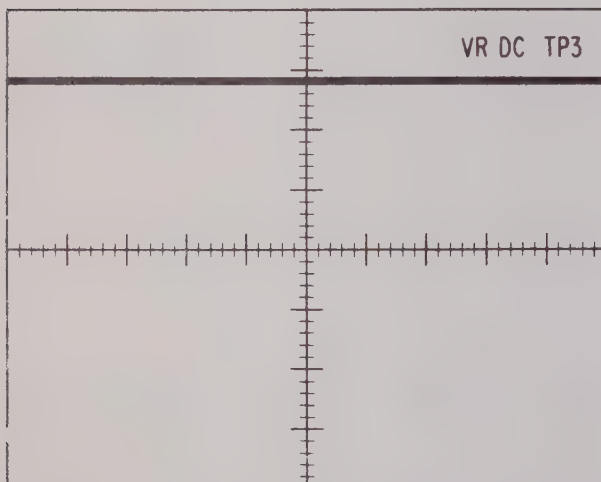
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 7, TP's VRDC [TP3] and VSDC [TP4])



Proper signal:



T/D = 0.1ms
V/D = 20mV
T = INT/AUTO

} ABOVE INDICATION

- A. If the DC signals are not as shown, replace the faulty Phase Rectifier.
- B. If the signals are as shown go to step 17.

17. Check the Active Filter board.

Set oscilloscope controls:

Time per Division = 0.1ms

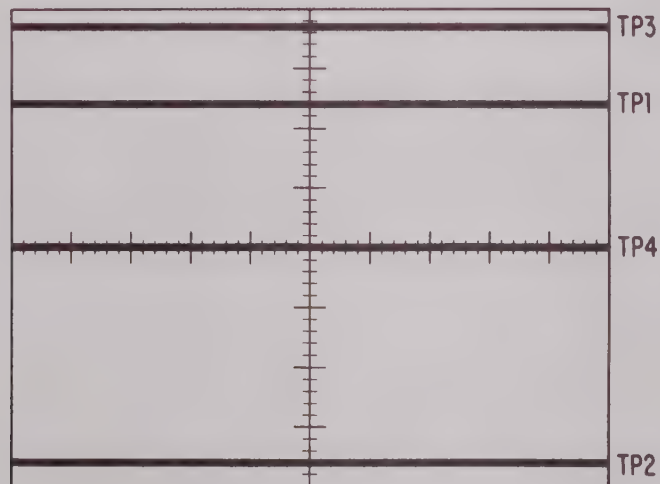
Volts per Division = 0.5V

Trigger = Int/Auto

Connect scope probe: (board 18, TP's 1,2,3, and 4)



Proper signal:



- A. If the signals are not as shown, replace the faulty Active Filter PC board.
- B. If the signals are as shown, go to step 18.

18. Check the A/D Linear and Digital boards.

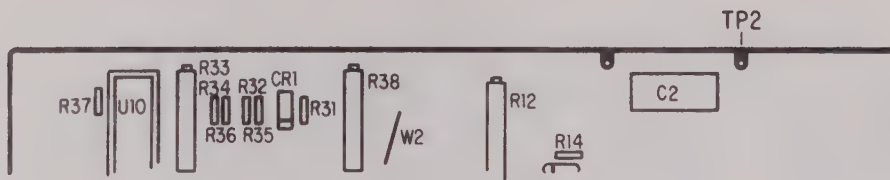
Set oscilloscope controls:

Time per Division = 0.1ms

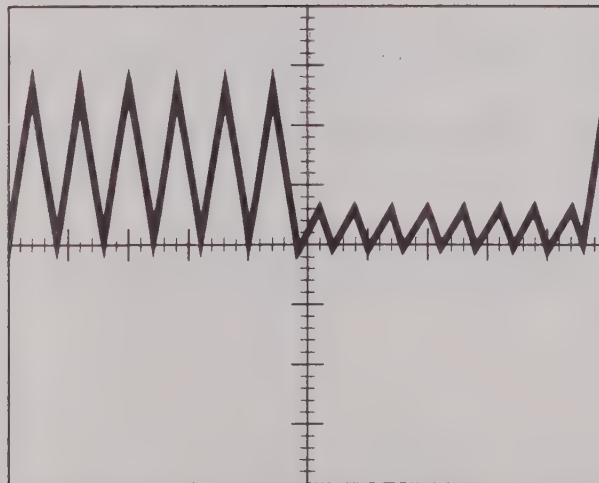
Volts per Division = 0.5V

Trigger = Int/Norm

Connect scope probe: (board 16, TP 2)



Proper signal:



- A. If the signals are not as shown, replace the faulty A/D Linear and A/D Digital PC boards.
- B. If the signals are as shown but the problem still exists, replace the faulty A/D Digital, CPU, or Display PC boards.

4.3.4 Options Troubleshooting Procedure

This section of the troubleshooting procedure isolates a problem to a particular option (when more than one option is installed). The troubleshooter should read and become familiar with appendix A in this manual. Pay particular attention to the programming and installation procedures for each option. Once the malfunctioning option board is found, more extensive troubleshooting can begin, or it can be replaced and sent to the factory for repair. The troubleshooting procedure should be applied only after determining that the Model 296 is at fault. Figure 4-7 Options Troubleshooting Summary is a flow indication for the procedure that follows.

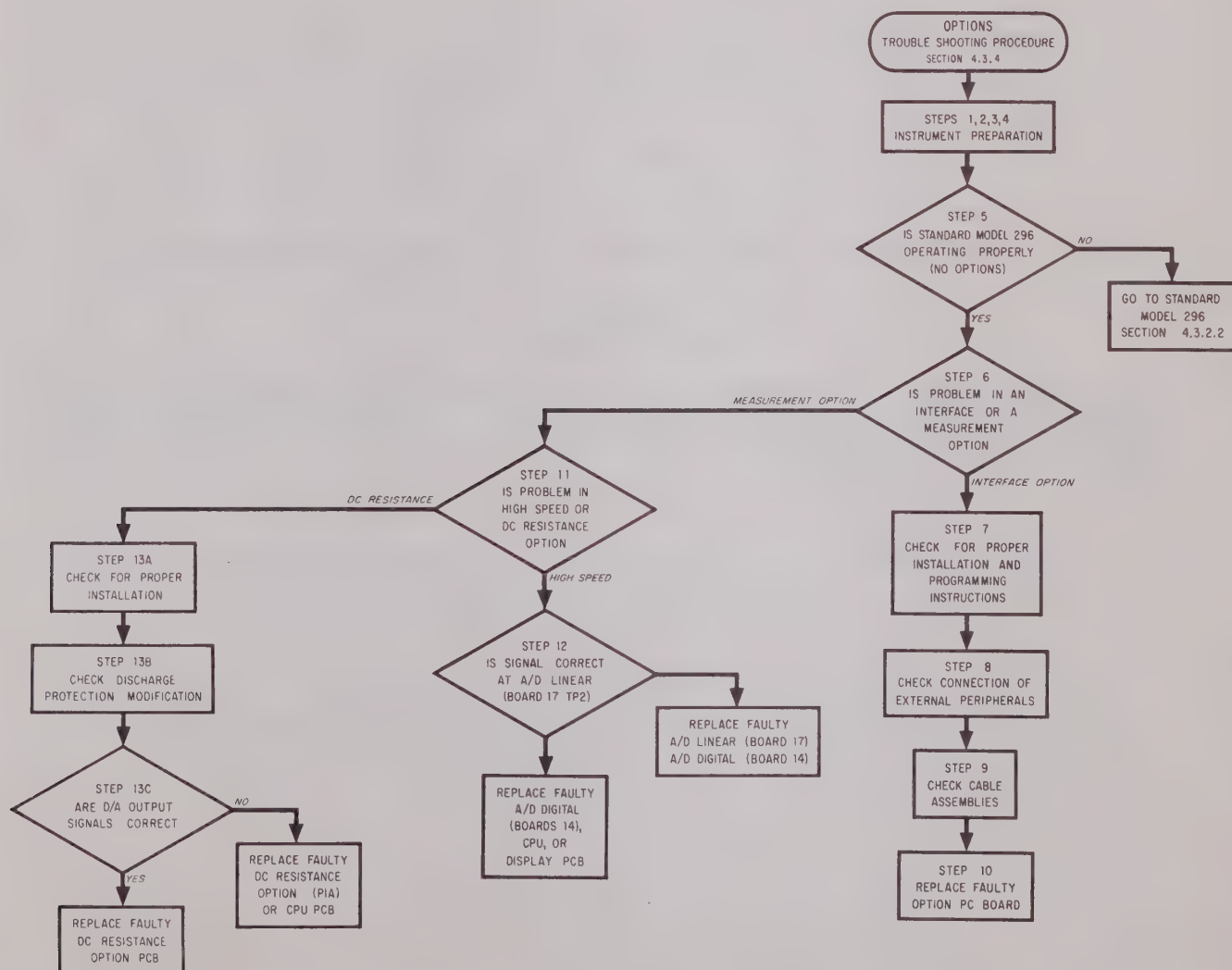


Figure 4-7. Options Troubleshooting Summary

1. Turn instrument power OFF.
2. Remove the top cover.
3. Visually check the portion of the instrument in which the trouble is suspected. Make sure the option PC boards are installed in their proper locations (see Appendix A).
4. Remove all option PC boards.
5. Turn power ON. Make sure the standard Model 296 is operating properly.
 - A. If the standard 296 is not measuring properly, go to the Standard Model 296 Troubleshooting section in this manual.
 - B. If the standard 296 is measuring properly, go to step 6.
6. Plug in each option, one at a time, until the problem reappears.



WHEN PERFORMING ANY CALIBRATION OR MAINTENANCE OPERATION, DO NOT REMOVE OR REPLACE CIRCUIT BOARDS WHILE THE POWER IS TURNED ON. FAILURE TO TURN POWER OFF MAY RESULT IN ELECTRIC SHOCK AND/OR DAMAGE TO THE INSTRUMENT.

- A. If the problem is in an interface option (GPIB, Card Reader, Teletype, or Handler options) go to step 7.
- B. If the problem is in a measurement option (High Speed Measurement option or the DC Resistance Measurement option) go to step 11.

Interface Options

7. Check the option for proper installation and programming instructions (see Appendix A).
8. Check the connection of external peripherals.
9. Check the cable assembly between the 296's rear panel and the option connector (refer to wiring tables in Appendix A).
10. Replace the faulty option PC board.

Measurement Options

11. Which option is installed, High Speed or DC Resistance?
 - A. High Speed option go to step 12.
 - B. DC Resistance option, go to step 13.

12. Check the High Speed Measurement option.

Model 296 setup:

Set to measure F_p and S. Push    

Set to high frequency. Push  FREQ

Set to high voltage. Push  VOLTAGE

Set to 150nF range.

Push RANGE  1 5 0  n  

Remove averaging.

Push  0 0 0 8 0  SECONDS  

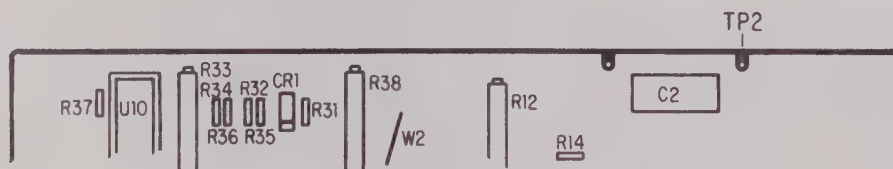
Set 0.1s settling time.

Push SETTLING TIME  0 1  SECONDS  

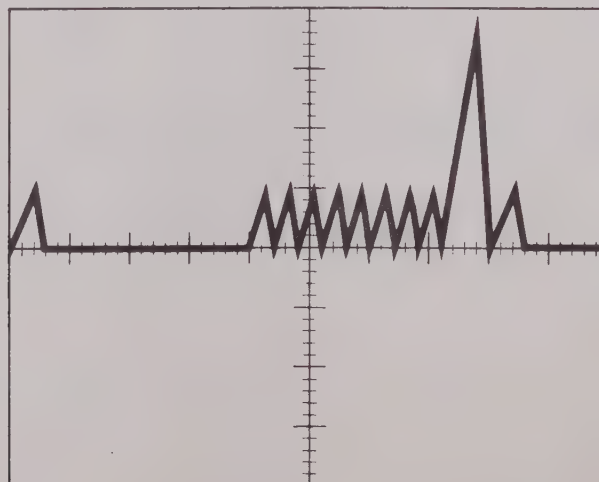
Set oscilloscope controls:

Time per Division = 10ms
 Volts per Division = 2V
 Trigger = Int/Norm

Connect scope probe: (board 17, TP 2)



Proper signal:



- A. If the signal is not as indicated, replace the faulty A/D Linear (board 17) and the A/D Digital (board 14) PC boards.
- B. If the signal is as indicated but the problem still exists, replace the faulty the A/D Digital (boards 14 and 15), CPU, or Display PC boards.

13. Check the DC Resistance Measurement option.

- A. Check for proper installation of the DC Resistance Option (refer to Appendix A).
- B. Make sure wire jumpers W1, W2, W3, and W4 are removed from the Discharge Protection PC board and that relays K1 and K2 are properly installed.
- C. Check the PIA (U9) output signals on the DC Resistance PC board. See Table A-8 in this manual.
- D. If the output signals are not as indicated, replace the PIA (U9) and/or the CPU PC board.

4.3.5 Checking Individual Components

The following methods are provided for checking the individual components. Components which are soldered in place can sometimes be checked by disconnecting one end to isolate the measurement from the effects of surrounding circuitry.

1. TRANSISTORS. It is always best to check transistor operation under operating conditions. Transistors that are soldered to the circuit board should first be checked in-circuit using a dynamic transistor tester; then a replacement can be substituted to verify that the old transistor is bad. Socketed transistors can be checked by substituting a component known to be good; however, be sure that circuit conditions are not such that a replacement might also be damaged. If substitute transistors are not available, check the old transistor out-of-circuit using a dynamic tester. Be sure the power is off before attempting to remove or replace any transistor.
2. INTEGRATED CIRCUITS. Analog IC's such as comparators and operational amplifiers can usually be checked in-circuit with a voltmeter or test oscilloscope. An understanding of the device and circuit operation is essential for this type of troubleshooting. (For example, an op amp can be tested by measuring the input and output circuit voltages and comparing this ratio to the ratio of input and feedback resistors.)

Analog IC's that are socketed can also be checked out-of-circuit using a dynamic tester such as the ESI Model 1234.

Digital IC's are best checked in-circuit using a logic probe or voltmeter. Use care when checking voltages and waveforms around DIP (Dual-Inline-Package) IC's so that adjacent leads are not shorted together. A convenient means of connecting a test probe to 14 and 16 pin IC's is with an IC test clip. This device also doubles as an extraction tool.

3. DIODES. A diode can be checked for an open or shorted condition by measuring the resistance between terminals with an ohmmeter set to the R X 1k scale. The diode resistance should be very high in one direction and very low when the meter leads are reversed.



DO NOT USE AN OHMMETER SCALE THAT HAS A HIGH INTERNAL CURRENT.
HIGH CURRENTS MAY DAMAGE THE DIODES UNDER TEST.

4. RESISTORS. Check resistors with an ohmmeter. Resistor tolerance is given in the Parts List. Resistors normally do not need to be replaced unless the measured value varies widely from the specified value.
5. CAPACITORS. A leaky or shorted capacitor can be detected by checking resistance with an ohmmeter on the highest scale. Use an ohmmeter that will not exceed the voltage rating of the capacitor. (Be careful to observe correct polarity when checking electrolytic capacitors.) The resistance reading should be high after initial charge of the capacitor. An open capacitor can best be detected with a capacitance meter, or by checking whether the capacitor passes AC signals.

4.4 CORRECTIVE MAINTENANCE

Corrective maintenance consists of component replacement and instrument repair.

4.4.1 Obtaining Replacement Parts

Standard Parts. All electrical and mechanical replacement parts for the Model 296 can be obtained from Electro Scientific Industries, Inc. However, many of the electronic components can be obtained locally in less time than is required to order them from ESI. Before purchasing or ordering replacement parts, check the parts list for value, tolerance, rating, and description.

NOTE: When selecting replacement parts, it is important to remember that the physical size and shape of a component may affect the performance of the instrument. All replacement parts should be direct replacements unless it is known that a different component will not adversely affect instrument performance.

Order all special parts directly from Electro Scientific Industries.

4.4.2 Component Replacement

WARNING

DISCONNECT ALL POWER TO THE INSTRUMENT BEFORE REPLACING COMPONENTS. FAILURE TO TURN POWER OFF MAY RESULT IN ELECTRICAL SHOCK AND/OR DAMAGE TO THE INSTRUMENT.

Semiconductor Replacement. Replacement semiconductors should be of the original type or a direct replacement. If the replacement semiconductor is not of the original type, check the manufacturer's basing diagram for proper lead identification.

Display LED's. When replacing front-panel LED's (light emitting diodes), be sure to place the new ones in the same exact alignment with the other LED's to facilitate reassembly. When soldering LED's, use the minimum heat required to do the job.

Free-Standing Components. When replacing any components that are free-standing (not directly mounted to circuit boards), be sure to place the new components in the same physical location and position as the old components. If this is not done, there may be a possibility of components touching and causing a short circuit.

4.4.3 Repackaging for Shipment

If the Model 296 is to be shipped back to ESI for service or repair, attach a tag showing: owner (with address) and the name of an individual at your firm that can be contacted, complete instrument serial number, and a description of the service required.

Save and re-use the package in which your instrument was shipped. If the original packaging is unfit for use or not available, repackage the instrument as follows:

1. Obtain a carton of corrugated cardboard having inside dimensions of not less than six inches more than the instrument dimensions; this will allow for cushioning.
2. Surround the unit with polyethylene sheeting to protect the finish of the instrument.
3. Cushion the instrument on all sides by tightly packing dunnage of urethane foam between the carton and the instrument allowing three inches on all sides.
4. Seal the carton with shipping tape or an industrial stapler.

SECTION 5

PARTS LIST AND DIAGRAMS

5.1 MAINFRAME PARTS

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
F1	Fuse 0.1A, Slo-Blo	09227
F2, F3	Fuse, 0.5A	01802
FL1	Filter, Receptacle, Fused	40002
S1	Switch, Power	23164
T1	Transformer, Power	41226
T2	Transformer, Coupling	41450
	Circuit Assembly, A/D Converter	40689
	Circuit Assembly, A/D Converter II	40702
	Circuit Assembly, Gain Channel	40935
	Circuit Assembly, Phase Rectifier	40941
	Circuit Assembly, Sig Amp and Ref Gen	40943
	Circuit Assembly, Power Amp	41192
	Circuit Assembly, Synchronous Integrator	41194
	Circuit Assembly, Oscillator	41196
	Circuit Assembly, Active Filter (old)	41221
	Circuit Assembly, Active Filter (new)	42978
	Circuit Assembly, Range Resistors	41223
	Circuit Assembly, Preamp and Level Regulator	41225
	Circuit Assembly, Keyboard	41269
	Mother Board, Righthand Assembly	41279
	Mother Board, Lefthand Assembly	41284
	Circuit Assembly, Display Board	41329
	Circuit Assembly, CPU Card	41492
	Circuit Assembly, Power Supply Board	41693
	Circuit Assembly, Protection Board	42675
	Front Panel	41295
	Back Panel	41282
	Top Cover	41264
	Bottom Cabinet	41265
	Bezel	41263
	Side Cabinet	41266
	PCB Rail	41307
	Card Guide Rail 13.0 Inch	41496
	Card Guide Rail 9.0 Inch	41495
	Front Panel, Display	41744
	Keyboard Kit	41369
	Button (White)	41191
	Button (Red)	41557
	Center Rail, Lefthand	41697
	Center Rail, Righthand	41698
	Card Guide	41846
	Instruction Card, Pull-out	42032
	Bracket, Power Switch	41487

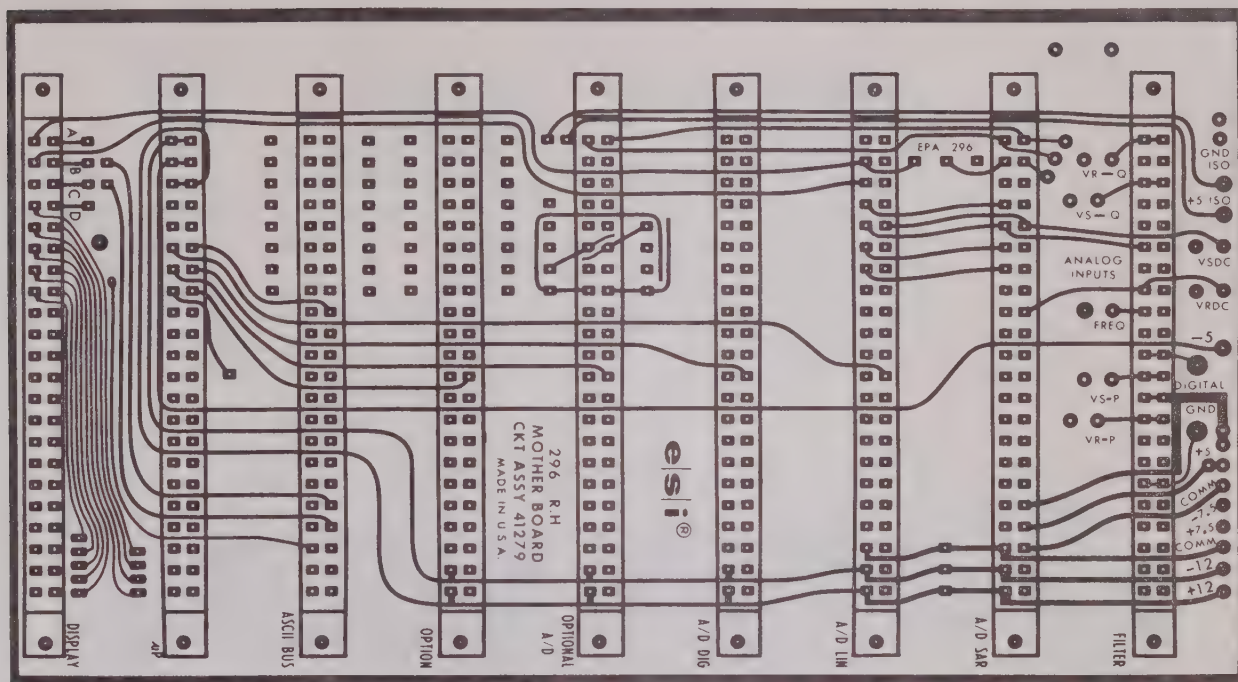
<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
	Strip, Cover	42415
	Bail, 12 Inch	24007
	Feet	08739
	Bracket, Transformer Mounting	41595
	Pushrod	24866
	Fan	27829
	BNC Connector	41820
	Finger Guard, Fan	41552
	Panel, Binding Post	41848
	Display Panel (Plastic)	41847
	Binding Post	01435
	Line Cord	24077
	Instruction Manual	41909
	Filter, Fan	41527
	Cover, Receptacle	42285
	Diode, MR1121	25688
	Diode, Mounting Kit	29534
	Insulator, Mica	41215
	Insulator, Mica	24328
	Socket	12262
	Capacitor, 0.22 μ F, Disc, 100V, 10%	13680
	Regulator, LM323k	24010
	Regulator, LM340T-5	20699
	Regulator, LM34/P-12 or MC78M12-CP	41877
	Regulator, LM320T-5 or MC7905-CP	41876
	Capacitor, 2.2 μ F, 20V, Tant	13283
	Connector, 24 Pin, IEEE Receptacle	42407
	Connector, 36 Pin, Receptacle	15739
	ESI Medallion	01946
	Fuse Post	03074
	Capacitor, 8000 μ F, 15V	21216
	Resistor, 100 Ω , 1/4W, 10%	13907

5.14 RH MOTHER BOARD CIRCUIT ASSEMBLY (Part No. 41279)

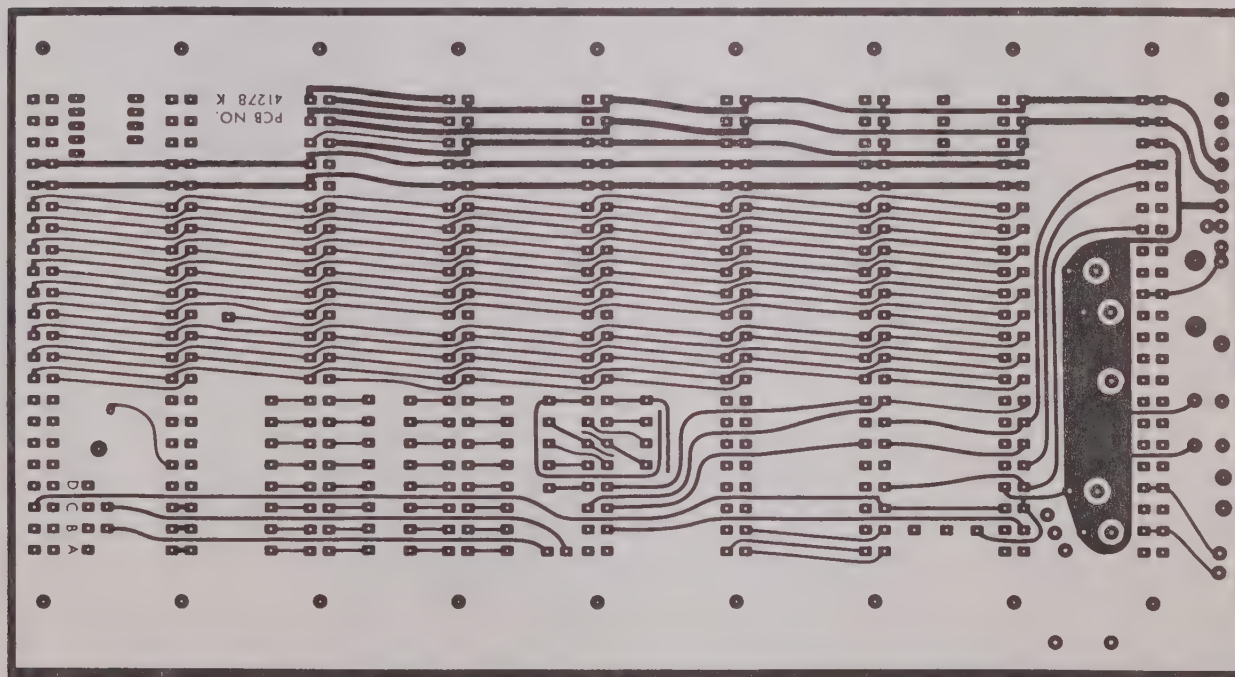
CIRCUIT NO.	DESCRIPTION	ESI PART NO.
-------------	-------------	--------------

Connector, 44 Pin

27817



FRONT SIDE



BACK SIDE

Figure 5-13. Part No. 41279

5.15 LH MOTHER BOARD CIRCUIT ASSEMBLY (Part No. 41284)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
A1	Assembly, R-L Network	29524
C1	Capacitor, 0.22 μ F, 100V, WMF	09950
C2	Capacitor, 0.47 μ F, 200V, MMW	12122
C5	Capacitor, 20pF, 600V, Poly	20926
CR1	Diode, 1N4005	01779
CR2-CR4	Voltage Clamp, 9VDC	42632
R1	Resistor, 22M Ω , 10%, 1/4W	13978
R2	Resistor, 100 Ω , 10%, 1/4W	13907
	Connector, 44 Pin	27817
R3	Resistor, 10k Ω , 10%, 1/4W	13933

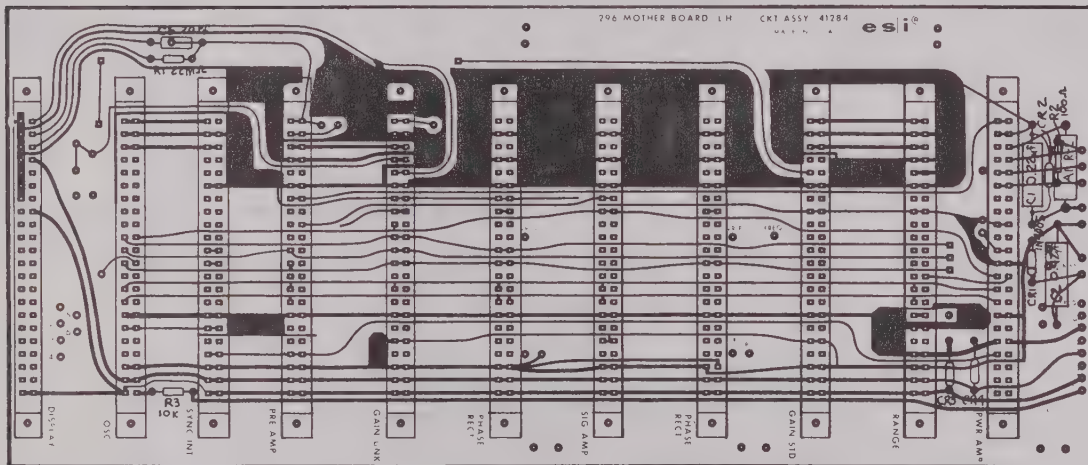
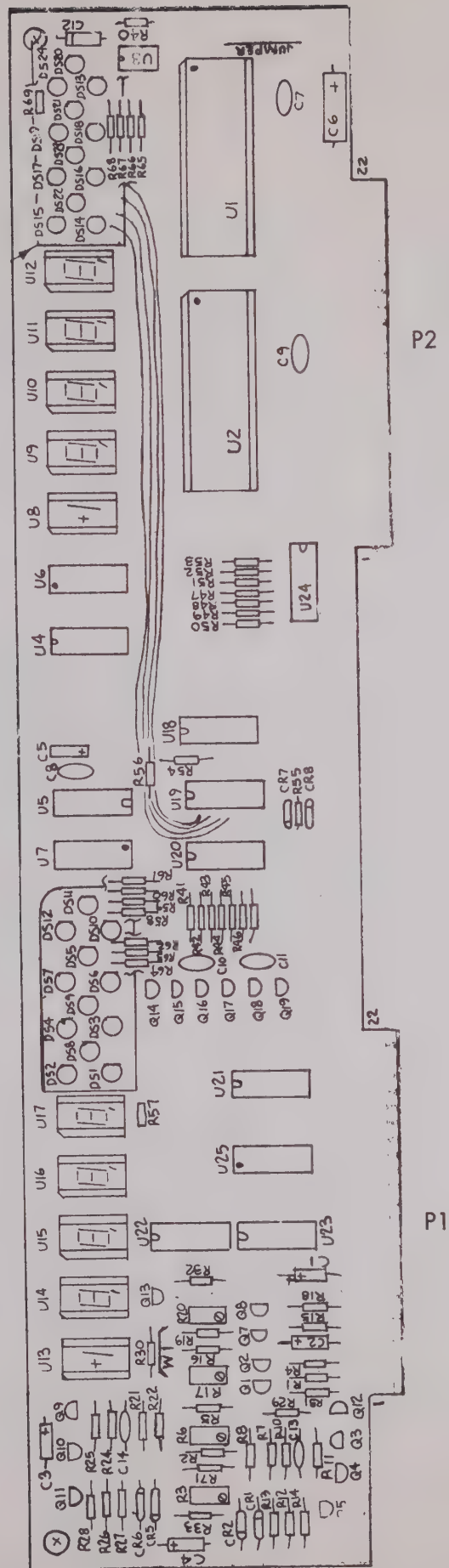


Figure 5-14. Part No. 41284

5.16 DISPLAY BOARD CIRCUIT ASSEMBLY (Part No. 41329)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1-C5	Capacitor, 22 μ F, 10V, Tant	18852
C6	Capacitor, 100 μ F, Electrolytic, 12V	06157
C7-C11	Capacitor, 0.01 μ F, Disc Ceramic, 50V	12144
C12	Capacitor, 0.47 μ F, 100V, 10%	13653
C13, C14	Capacitor, 3.3pF, Disc	01925
CR1, CR2, CR5-CR8	Diode, 1N914A	12356
DS1-DS24	LED, PC Mount	45240
Q1-Q3, Q5, Q7-Q9, Q11	Transistor, 2N3904	18751
Q4, Q10, Q12-Q19	Transistor, 2N3906	18754
R1, R4, R15, R18, R46-R55	Resistor, 2.2k Ω , 5%, 1/4W	13924
R2, R5, R16, R19, R31, R32, R41-R45, R73	Resistor, 220 Ω , 5%, 1/4W	13911
R3, R6, R17, R20	Trimpot, 10k Ω , 20 Turn	41902
R7, R8, R21, R22	Resistor, 2k Ω , 1%, 1/4W	21733
R10, R11, R24, R25	Resistor, 100 Ω , 10%, 1/4W	13907
R12, R26	Resistor, 6.8k Ω , 10%, 1/4W	13930
R13, R27	Resistor, 15k Ω , 10%, 1/4W	13935
R14, R28-R30	Resistor, 680 Ω , 10%, 1/4W	13917
R33	Resistor, 806 Ω , 1%, 1/4W	21729
R40	Resistor, 4870 Ω , 1%, 1/4W	20660
R56-R69	Resistor, 10 Ω , 10%, 1/4W	13895
R71	Resistor, 2.49k Ω , 1%, 1/4W	21734
U1, U2	IC, 6820, PIA, AMI, 40 Pin	41292
U3	IC, 555, Timer	20721
U4, U5	IC, 7447, BCD to Seven Segment Decoder	20691
U6, U7	Resistor, DIP Pack, 8 ea, 100 Ω	20714
U8, U13	Display, $\pm$ 1, Monsanto 4630	41349
U9-U12, U14-U17	Display, Seven Seg., Monsanto 4610	41350
U18	IC, 7406, Hex Inverter, Open Coll	20678
U19, U20	IC, 7445, BCD to Decimal Decoder	20609
U21	IC, 74148, Priority Encoder	41347
U22-U24	IC, 7407	24076
U25	Resistor, DIP Pack, 15 ea, 3.3k Ω	22947
	Socket, 14 Pin DIP, PC Mount	19189
	Socket, 40 Pin DIP, PC Mount	41342
	LED Alignment Block, Lefthand	42398
	LED Alignment Block, Righthand	42397
	Shield, PC Board	41467

Figure 5-15. Part No. 41329



APPENDIX A

OPTIONS OPERATION

A.1 INTRODUCTION

Options for Model 296, 296V and 410 LRC meters are plug-in circuit assemblies. Three sites are available for options in the 296 and 296V and only two are available in the Model 410 (see Table A-1). One option from each group can be plugged in at a time and can be plugged into only the one site assigned. Refer to Figure A-1 for location of options.

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

CAUTION

TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING OPTIONS.

OPTIONS GROUP	OPTION*		
	MODEL 296	MODEL 296V	MODEL 410
AUXILIARY FUNCTIONS GROUP	HIGH SPEED MEASUREMENT DC RESISTANCE MEASUREMENT		
AUXILIARY OUTPUT GROUP	HANDLER INTERFACE	HANDLER INTERFACE	HANDLER INTERFACE
REMOTE PROGRAMMING GROUP	GPIB CARD READER INTERFACE TELETYPE INTERFACE	GPIB CARD READER INTERFACE TELETYPE INTERFACE	GPIB CARD READER INTERFACE TELETYPE INTERFACE

*Only one option from each group allowed at one time.

Table A-1.

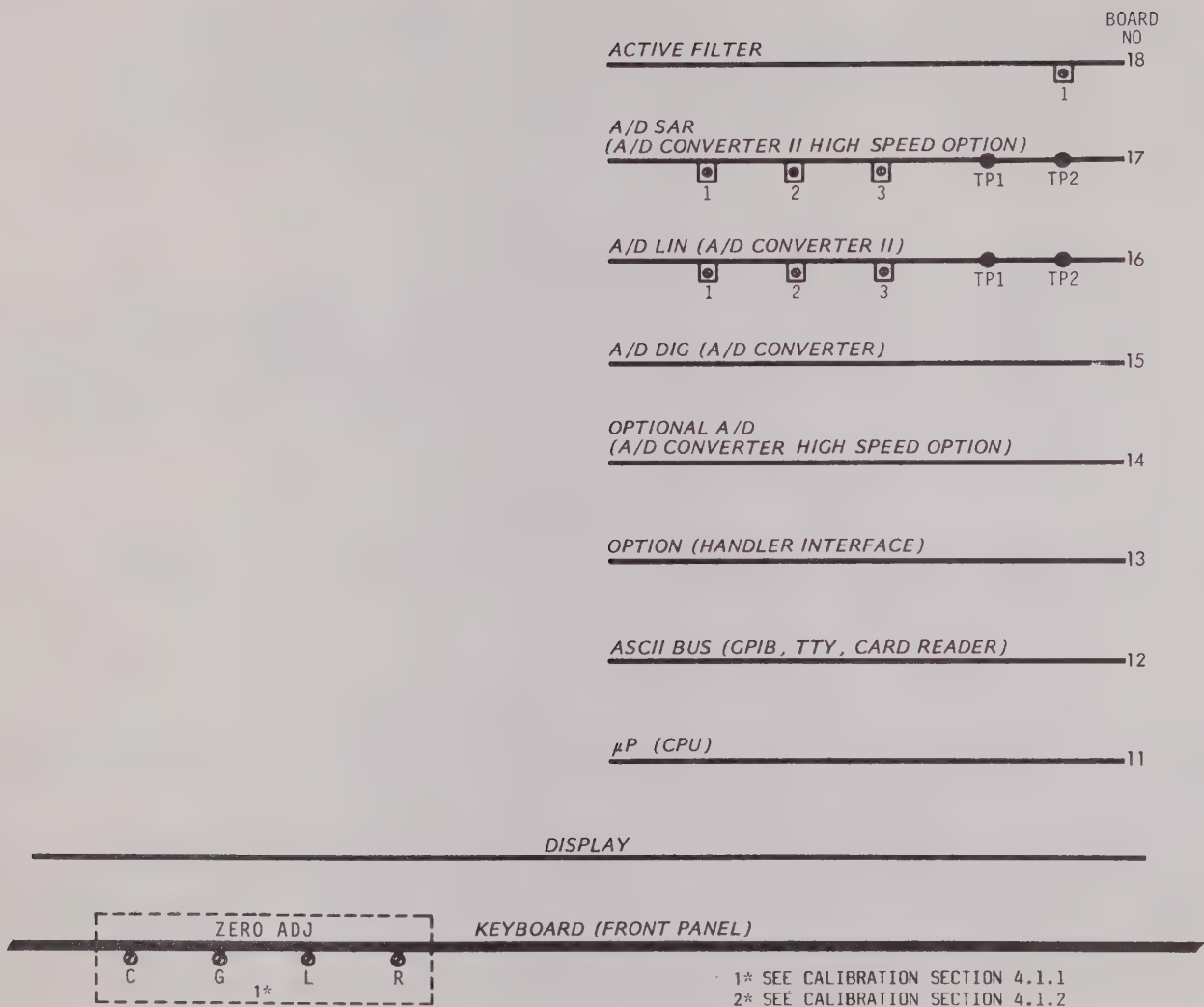


Figure A-1. Option Locations

A.2 REMOTE PROGRAMMING AND INTERFACE OPTIONS OPERATION

Table A-2 gives programming commands for the GPIB, teletype and card reader interface options. With any of these interfaces installed, Model 296, 296V and 410 LRC meters may be programmed in the same manner as from the front panel.

The remote programming function characters listed in Table A-2 must be transmitted to LRC meter only when a mode change is desired. Functions remain in effect until another function is transmitted or power turned off.

An X (red button) must precede each red button function just as for manual programming. An exception is when programming a range multiplier such as μF or $m\Omega$. In this case only one X is required.

Output commands are very important to remote programming operation. The output commands dictate the method in which LRC meter sends its data to various peripheral devices. They must be a part of the programming command string. When addressed to TALK by the GPIB interface or receiving a TALK command (') through the TTY interface one of the following commands must be used:

-) Output when addressed to TALK (or commanded to output information). This immediately outputs both displays. It is useful for examining functions entered such as nominal values, settling time, band limits, etc.
- * Outputs data when addressed after a measurement is complete. Also sets SRO line low to indicate end of measurement. It is useful when an external device is initiating single measurements and needs output data upon completion of measurement.

Two other output commands are available:

- [Output when measurement complete. This command is equivalent to test code 0009. In this mode the LRC meter outputs its data immediately after a measurement is completed. No TALK command need be sent. It is useful when the controlling device (such as a TTY or printer) requires output data after measurement without having to send a TALK command. This command is not recommended for IEEE Bus use because data usually cannot be handled until requested. It can be used to continuously output results of a changing measured value such as encountered in a temperature test.
-] Cancels [so that output is again available only when addressed or commanded to TALK.

ASCII CHARACTERS for GPIB (IEEE 488), TTY (SERIAL) and CARD READER					HOLLERITH TO ASCII													ASCII CHARACTER ^②	
ASCII CHARACTER	KEYBOARD FUNCTIONS																		
	MODELS 296 and 296V		MODEL 410																
	WHITE	RED ^①	WHITE	RED ^①	9	8	7	6	5	4	3	2	1	0	-	&			
F	HI FREQ	LO FREQ	HI VOLTAGE	B/X														F	
9 or O	9	Ω	9	Ω														9	O
8 or L	8	H	8	H														8	L
7 or C	7	F	7	F														7	C
T	T	S	T	S														T	
R	RANGE	DC OHMS ^{999 ONLY}	RANGE	D Correction														R	
V	HI VOLTAGE	LO VOLTAGE	MED VOLTAGE	LO VOLTAGE														V	
6 or Q	6	Q	6	Q														6	Q
5 or D	5	D	5	D														5	D
4 or %	4	%	4	%														4	%
A or †	†	AUTO	†	AUTO														A	
=	NOM VALUE	Δ	NOM VALUE	Δ														=	
E	PRL EQUIV CKT	SER EQUIV CKT	PRL EQUIV CKT	SER EQUIV CKT														E	
3 or M	3	M	3	M														3	M
2 or K	2	k	2	k														2	K
1	1	m	1	m														1	
H or +	+	HOLD	+	HOLD														H	
B	SET POINT		SET POINT															B	
G	START	SINGLE	START	SINGLE														G	
- or U	-	μ	-	μ														-	U
0 or N	0	n	0	n														0	N
. or P	.	p	.	p														.	P
X	Red Button	Red Button	Red Button	Red Button														X	
S	SETTLING TIME	SECONDS	SETTLING TIME	SECONDS														S	
CHARACTER	REMOTE PROGRAMMING FUNCTIONS																		
)	output when addressed																	)	
*	set service request ^③																	*	
:	lock keyboard and turn on RMT light																	:	
X:	unlock keyboard and turn off RMT light																	X:	
&	delete all limits data, reset limits counter																	&	
X&	reset limits counter																	X&	
{	output when measurement is completed																	{	
}	no output																	}	
'	TALK command for TTY interface																	'	
\	delete ECHO routine, set ECHO routine																	\	

① An X must precede each character to obtain red button functions

② ■ or ■■■ indicates alternate choices. Example: In line 2 either 9 or O can be used; 9 is set as shown by ■, O is set as shown by ■■■

③ Output when addressed after measurement complete

Table A-2. Model 296, 296V and 410 Programming Commands for GPIB, TTY and Card Reader Interfaces

The & and X& commands serve an important function when programming limits operation. Each time the SET POINT command is sent (or button pushed) an internal counter is incremented. This counter monitors which set point is to be set next. Since limits must be set from limit 1 up, it is necessary to initialize the counter when setting limits to prevent accidentally programming the wrong limit. An X& command resets the counter so that the next press of the set point returns to number 1 set point, the & command clears all previously set limits and resets the counter. The X& command allows a single limit to be reset without affecting others by programming X& then the number of SET POINT commands necessary to increment the counter to the desired limit. Example: X&BBB - resets then steps to the third limit and is ready to accept a value to store as limit 3.

A.3 GPIB GENERAL PURPOSE INTERFACE BUS OPTION

The GPIB Interface option, ESI Part No. 42404, enables Model 296, 296V and 410 LRC meters to communicate on the bus structure as defined by IEEE 488-1975 specification. The LRC meters will operate in either the TALK or LISTEN mode and uses 7 bit ASCII character format. Table A-2 lists the ASCII characters for functions and operating instructions. All front panel controls and special codes are programmable via the GPIB, including front panel lock-out.

The advantage of GPIB programming is that several instruments can be operated on a common bus with one controller. Each has a unique address which only that instrument recognizes.

NOTE: This option may cause the LRC meter display to appear erratic. Erratic displays occur when the microprocessor is performing a handshake routine for data presented on the data bus. This happens regardless of which instrument along the data bus the data is intended.

A.3.1 Hardware Included

IEEE Interface Circuit Assembly	Part No. 42132
---------------------------------	-------------------

A.3.2 Installation

WARNING

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CAUTION

TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

The IEEE circuit assembly is installed by plugging it into the location marked ASCII BUS (12), see Figure A-1.

A.3.3 Operation

Bus addresses for Models 296, 296V and 410 are set at the factory to 65 for TALK and 33 for LISTEN. Addresses may be changed with the switches on the interface PC board. Both TALK and LISTEN addresses are set by the same switch as shown in Figure A-2. TALK address is achieved by adding 64 to the switch setting, LISTEN address by adding 32 to the switch setting. Switches operate in a BCD configuration.

Only the five least significant bits (first five switches from the right) are used to set the address.

The second and third switches from the left should not be changed from their off position. The first switch from the left can be on to enable the LRC meters to transfer data to a printer after measurement is completed. It must be off when LRC meters are used with the IEEE bus. Programming test code 0009 (see Section 2.3.9 of the Model 296 manual) is equivalent to setting the switch ON.

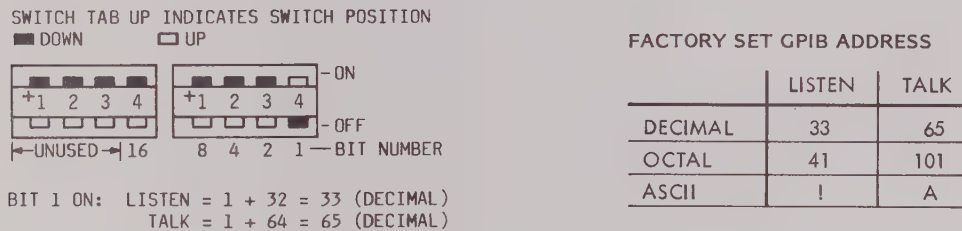


Figure A-2.

Programming via the GPIB follows the same sequence as programming from the front panel. A typical command string for Model 296 would look like this:

XFR100XUCXEXDXG*

where: XF = low frequency (red button FREQ)
R = range (also puts unit in range hold mode)
100XUC = 100 μ F
XE = series equivalent circuit
XD = dissipation factor
XV = low voltage
XG = single measurement mode
* = output data after measurement complete when addressed

This string programs the instrument to measure series capacitance on the 100 μ F range with D as loss function, in the range hold mode, low frequency, low voltage mode, and single measurement mode.

A Model 296V output string for the above example would look like this:

N FS+08534E-2, D+00025E-4

- exponent for measured D value
- decimal point position
- 5 digits, plus sign for measured D value;
same as righthand front panel display
- D for dissipation factor
- Q for quality factor
- R for resistance (ohms)
- S for conductance (siemens)
- separates reactance and loss measured quantities
- exponent for measured FS value
- decimal point position
- 5 digits, plus sign, for measured FS value
- FS, FP, HS, HP indicating capacitance or inductance, series
or parallel; same as lefthand front panel display
- N for normal measurement
- O for overload
- D for absolute deviation measurement
- % for percent deviation measurement

Measured values are output in floating point format, 5 digits and an exponent. In the example the measured capacitance value is +08534E-2 which represents $8534 \times 10^{-2} \mu\text{F}$ or $85.34 \mu\text{F}$. Values for capacitance are expressed in μF (microfarads) and values for conductance in μS (microsiemens). Inductance and resistance are expressed in H (henries) and Ω (ohms); μH for 10kHz and 20kHz options. Blank displays are transmitted as ? to indicate that display does not contain data.

An example of Model 296, 296V or 410 operation through the GPIB bus by a Tektronix Graphics Terminal Model 4051 is shown.

```
100 on SRQ THEN 180      Directs Model 4051 to address 180 when SRQ
                           interrupt is received
```

110 PRINT "COMMAND";	Operator enters command string for range, etc. Command string must contain an asterisk (*) to assure data acceptance after measurement complete.
----------------------	--

120 INPUT A\$ Places input command string in 4051 memory location A\$.

```
130 PRINT @ 1:A$      Model 4051 outputs string (stored in location
                        A$) to LRC meter. (LRC meter should at this
                        point be set to desired functions.)
```

```
140 for N=1 TO 10      Instructions to perform 10 measurements.
```

```
150 PRINT @ 1:XG      4051 commands LRC meter to make a single
                        measurement.
```

160 WAIT	Stores location 170 as return address after servicing SRQ interrupt. Waits for SRQ interrupt indicating measurement complete. When SRQ is received goes to address 100 for interrupt service instructions.
170 NEXT N	Increments N and returns to address 140 for next measurement.
180 INPUT @ 1:A\$	4051 commands LRC meter to send it the measured data (LRC meter TALKS) after the SRQ line has been activated by LRC meter (end of measurement). (Model 4051 stores measured data in memory location A\$.) An asterisk (*) must be a part of the command string for data output only after measurement complete.
190 PRINT A\$	4051 prints measured data stored in A\$.
200 RETURN	Program returns to address 170 (stored by WAIT statement 160).

Results

RUN COMMAND? R1500XPCX0*	Range 1500pF, series capacitance and resistance. The asterisk is a very important character for this program. It instructs LRC meter to return measurement results only upon completion of the measurement initiated by "XG" (see Table A-2).
-----------------------------	---

```

N FS+15384E-7,R-000001E+2
N FS+15384E-7,R+000000E+2
N FS+15385E-7,R+000000E+2
N FS+15383E-7,R+000000E+2
N FS+15384E-7,R+000000E+2
N FS+15383E-7,R+000001E+2 Measured data.
N FS+15384E-7,R+000000E+2
N FS+15384E-7,R+000000E+2
N FS+15383E-7,R+000000E+2
N FS+15383E-7,R+000000E+2

```

All programming is accomplished via the LRC meter's rear panel REMOTE connector. Table A-3 lists the function for each pin of the REMOTE connector.

Remote Connector Wiring

PCB CONNECTOR	REMOTE CONNECTOR PIN NUMBERS	FUNCTION
5	1	D0
2	2	D1
1	3	D2
6	4	D3
E	5	E01
A	6	DAV
B	7	NRFD
C	8	NDAC
F	9	IFC
D	10	SRQ
J	11	ATN
	12	COM
7	13	D4
3	14	D5
8	15	D6
4	16	D7
H	17	REN

Table A-3. GPIB Option

A.3.4 Calibration

The LRC meters need no adjustment, other than normal calibration, when the GPIB option is installed. The IEEE interface circuit assembly contains no service adjustments.

WARNING

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A.4 TELETYPE INTERFACE OPTION

The Teletype Interface option, ESI Part No. 42735, is used to interface Model 296, 296V and 410 LRC meters to three-wire serial bus systems. With this option installed the LRC meters can interface with:

20mA current loop systems
5V TTL level systems
RS232, $\pm 12V$ switched at ground systems

A.4.1 Hardware Included

Teletype Interface Circuit Assembly	Part No. 42763
-------------------------------------	-------------------

A.4.2 Installation

WARNING

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CAUTION

TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

The teletype interface circuit assembly is installed by plugging it into the location marked ASCII BUS (12), see Figure A-1.

The character format is 11 bits (see Figure A-4):

One start bit (1)
Seven data bits (2 thru 8)
Parity bit (no parity) (9)
Two stop bits (10, 11)



Figure A-4.

Available baud rates are:

75, 110, 135, 150, 200, 300, 600, 1200,
1800, 2400, 3600, 4800, 7200, 9600

Baud rates are selectable by changing jumper wires W3 and W4 (see Figure A-3). Wire jumper W3 selects the TALK baud rate and W4 selects the LISTEN baud rate.

LISTEN and TALK baud rates are asynchronous. Each can be at different rates than the other. This allows the TTY option to LISTEN using the mode selected by jumper W1 or W2 and to TALK using any of the three modes.

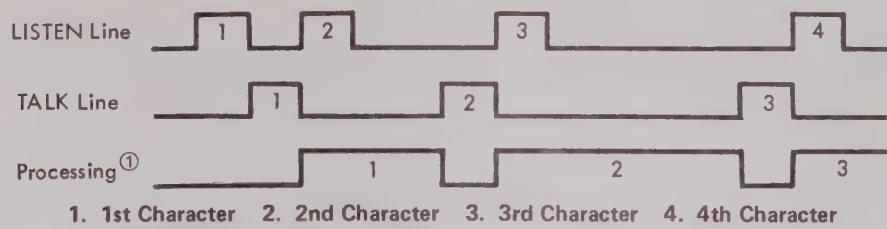
Example: With wire jumper W2 installed, the LISTEN baud rate may be set at 1200 while the TALK baud rate can be set over the entire range.

NOTE: At slow baud rates, the LRC meter displays may become erratic during the TALK function. Erratic displays occur when the microprocessor is performing a handshake routine for data presented on the data bus. This happens regardless of which instrument along the data bus the data is intended.

The TALK rate is controlled by the microprocessor and a character is not processed until the preceding character has been transmitted. The end of each TALK sequence is signaled by transmitting a carriage return, a line feed and a null period.

The LISTEN rate is character string dependent. Certain characters require more processing time, so care must be taken not to lose a character by transmitting characters to Model 296, 296V or 410 faster than it can process them. Baud rates above 2400 baud experience this problem and it is recommended to insert a 3ms wait loop between each character.

Optimum transmission speed can be achieved by using the Echo routine. Since the LISTEN data line is buffered and will hold one character, the controller can operate in a handshake mode using the Echo character to initiate transmission of the next character.



① Processing time is variable and dependent on the character.

Figure A-5.

Characters are ASCII format and the output string is the same as described in Remote Programming Section A.2. The ' character is the TALK command for the teletype interface. The controller sends a ' when it is ready to receive data. All programming is accomplished via the LRC meter's rear panel REMOTE connector. Table A-5 lists the function of each pin of the REMOTE connector.

Remote Connector Wiring

PCB CONNECTOR	REMOTE CONNECTOR PIN NUMBER	FUNCTION
5	1	+ TTY OUT
2	2	- TTY IN
1	3	+ TTY IN
6	4	- TTY OUT
A	6	DCD
B	7	RTS
F	9	IEE/2
	12	COM
7	13	RS232 IN
3	14	TTL IN
8	15	RS232 OUT
4	16	TTL OUT
H	17	D2

Table A-5. Teletype Interface Option

A.4.4 Calibration

Remote START capability is available with the teletype interface option. To initiate a START measurement, momentarily connect the RST pin of the REMOTE connector to ground.

The LRC meters need no adjustment, other than normal calibration, when the teletype interface option is installed. The teletype interface circuit assembly contains no service adjustments.

WARNING

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A.5 CARD READER INTERFACE OPTION

The Card Reader Interface option, Part No. 42736 or Part No. 43771, allow Model 296, 296V and 410 LRC meters to be programmed by preprogrammed cards, using a HP11301A Hollerith Card Reader. This simplifies programming, reduces setup time and allows easy, convenient storage of programs. The option consists of a card reader interface PC board and the card reader. The card reader is available either from ESI or Hewlett Packard.

Both options require a CPU circuit assembly exchange. ESI ships CPU circuit assembly Part No. 43826 and invoices an additional charge which is credited in full upon return of the standard Model 296 or 410 CPU circuit assembly Part No. 41491. Model 296V does not require this CPU circuit assembly exchange.

A.5.1 Hardware Included

	Part No.
Option 42736 (Card Reader Interface Kit)	
Card Reader Circuit Assembly	43399
CPU Circuit Assembly	43826
Card Reader to LRC Meter Cable Assembly	43675
HP Punch Cards (200)	43861
Hand Punch	44382
 Option 43771	
Card Reader Interface Kit (option)	42736
HP - Manual Card Reader	43776

A.5.2 Installation

WARNING

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CAUTION

TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

The Card Reader Interface Assembly is installed by plugging it into the location marked ASCII BUS (12), see Figure A-1. The card reader is connected to the LRC meter's rear panel REMOTE connector via the card reader to LRC meter cable assembly.

A.5.3 Operation

The Card Reader Interface PC Board receives data from the card reader. This data corresponds to the Hollerith code marked on the cards. The Hollerith code input is converted to binary code and compared to binary values pre-stored in a look-up table. When a binary number in the look-up table corresponds to the input binary number an equivalent ASCII code is generated and sent to the microprocessor which controls the instrument.

The recommended card reader is Hewlett Packard 11301A (an HP9870 card reader without a calculator interface). It is a small quiet desk top design with power supplied from Model 296, 296V or 410. It accepts 96 character Hollerith coded cards marked with either a very soft leaded pencil or punched holes (punched holes are recommended to insure the reliable transfer of information).

All programming is accomplished via the LRC meter's rear panel REMOTE connector. Table A-6 lists the function for each pin of the REMOTE connector.

Remote Connector Wiring

PCB CONNECTOR	REMOTE CONNECTOR PIN NUMBER	FUNCTION
5	1	D 7
2	2	D 11
1	3	D 0
6	4	D 6
E	5	D 1
A	6	CP/MD
B	7	ST/MI
F	9	D 3
	12	COM
7	13	D 8
3	14	D 12
8	15	D 9
4	16	D 4
H	17	D 5

Table A-6. Card Reader Interface Option

Refer to the Card Reader Option instruction manual, Part No. 43981, for further information concerning the card reader and programming Hollerith cards.

A.5.4 Calibration

The LRC meters need no adjustment, other than normal calibration, when the card reader option is installed. The card reader interface circuit assembly contains no service adjustments.

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

A.6 HANDLER INTERFACE OPTION

Handler Interface kits enable Model 296, 296V and 410 LRC meters to operate with a mechanical parts handler. The kit accepts a START signal to initiate measurements, provides a BUSY signal which may be used to arrest handler operation during test and offers a contact closure output corresponding to one of ten preselected limit bands (refer to instruction manual for limits operation).

Three standard handler interface kits are available. They are:

ESI Part No. 42436 -- For interfacing the Engineered Automation Auto-Sort Handler to the LRC meter via the ESI Model 1453 Handler Adaptor.

ESI Part No. 44339 -- For interfacing the Daymarc Type 147 and 149 handlers directly to the LRC meter.

ESI Part No. 44340 -- For interfacing Deval handlers to the LRC meter.

Contact the factory for information concerning the use of other part handlers with the Model 296, 296V or 410.

A.6.1 Hardware Included

	Part No.
Handler Interface Kit 42436	
Optional Interface Circuit Assembly	42073
Handler Interface Kit 44339	
Optional interface Circuit Assembly	44256
Handler Interface Kit 44340	
Optional Interface Circuit Assembly	44257

A.6.2 Installation

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.



TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

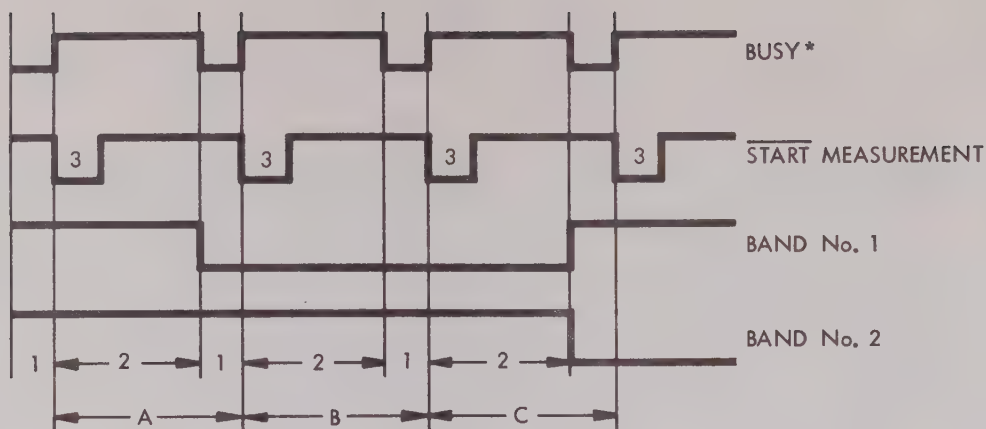
The Optional Interface Assembly is plugged into the OPTION location on the LRC meter's right-hand mother board (see Figure A-1).

Installation of the BNC to BNC cable assemblies and the Handler Interface cable assembly, for kit part number 42436, are dependent upon the component handler being used. The BNC cables interconnect the LRC meters HI and LO unknown terminals to the part handler's component contactors. The Handler Interface Cables make all logic connections between the LRC meters rear panel OUTPUTS connector and the component handler.

A.6.3 Operation

The Optional Interface provides the following functions:

1. START TEST - is the input to an opto-isolator, 4N28. It requires a holding current of 10 to 80mA to initiate a measurement.
2. BUSY - is the open collector output of an opto-isolator. This signal can be used to arrest handler operation during test.
3. Output Relays - contact closures that are selected according to preset limits, see LIMITS section of the LRC meter instruction manual. (One relay is closed at a time.) The relays are rated at 100VDC, 250mA switching current and 10 million operations. Higher currents can be switched with a possible reduction in operation life, especially if contacts arc on opening. Resistive loads are more desirable than inductive loads. For example, a 400mA, 15V, resistive load will not appreciably reduce life. Relays are on sockets for easy replacement.
4. 5V TTL (open collector) Outputs - are available at the rear panel OUTPUTS connector. They require the addition of a jumper wire in place of each output relay.



1. Handler Time -- User dependent.
 2. Measurement Time -- Dependent on range and functions. See measurement speed section of the manual.
 3. Initiate a measurement signal -- 5 ms* minimum.
- A. First part was in band No. 1.
 B. Second part was also in band No. 1
 C. Third part was in band No. 2
- * Contact factory for special modifications.

Figure A-6.

All handler interface operations take place via the LRC meter's rear panel OUTPUTS connector. Table A-7 lists the functions for each pin of the OUTPUTS connector.

PCB CONNECTOR	OUTPUTS CONNECTOR PIN NUMBER	FUNCTION
7	1	COMMON
J	2	BAND 0
H	3	BAND 1
F	4	BAND 2
E	5	BAND 3
D	6	BAND 4
C	7	BAND 5
B	8	BAND 6
A	9	BAND 7
6	10	BAND 8
5	11	BAND 9
2	16	BAND 10
	12	+5V (SYSTEM) OUT
	13	SYSTEM GROUND
8	14	START IN
4	18	BUSY OUT

Table A-7. LRC Meter OUTPUTS Connector Wiring

To assure proper electrical isolation and noise free operation, it is recommended the customer use his common and logic levels when interfacing to the LRC meter. If this is not possible +5V and common are provided at the rear panel OUTPUTS connector (see Table 1) for use by low noise controllers. It is cautioned that excessive noise impressed upon the system +5V supply can disrupt microprocessor operation. Current available from the +5V supply is approximately 250mA.

A.6.4 Calibration

The LRC meters need no adjustment, other than normal calibration, when a Handler Interface Kit is installed. The Optional Interface Assembly contains no service adjustments.

WARNING

TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.

A.7 HIGH SPEED MEASUREMENT OPTION

The High Speed Measurement Option, ESI Part No. 42445, reduces overall measurement time to less than 100ms for all measurement functions. A second set of A/D converters are required to measure loss, G/ω or R/ω , and reactance, C or L , thus eliminating one conversion period. The high speed option is very useful when interfacing Model 296, or 296V LRC meters with automatic handlers and generally is only used when in single measurement mode.

A.7.1 Hardware Included

A/D Linear Circuit Assembly	Part No. 40702
A/D Digital Circuit Assembly	40689

A.7.2 Installation

The high speed option circuit assemblies are installed as follows.

WARNING

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CAUTION

TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

1. Remove instrument's top cover.
2. Perform calibration, see paragraph A.7.4.
3. Replace top cover.

A.7.3 Operation

With the high speed option installed, the A/D converters, under control of the CPU, first measures any offset voltages that may appear in the A/D circuitry, then measures the ratio of selected dc voltages. The quantities measured by the original set of A/D converters are as follows:

$$\frac{G_p}{\omega} \text{ or } \frac{R_s}{\omega} = \frac{V_s \text{ dc } P}{V_r \text{ dc } Q}$$

AND

$$\frac{1}{\omega} = K \frac{V_r \text{ dc } P}{V_r \text{ dc } Q}$$

where:

$V_s \text{ dc } P$ -- A dc voltage proportional to the amplitude of the in-phase component (resistive or conductive) derived by using the 0° generator as a reference.

$V_r \text{ dc } P$ -- A dc voltage proportional to the amplitude of the 0° reference generator derived using the 0° reference generator as both signal and reference.

$V_r \text{ dc } Q$ -- A dc voltage proportional to the amplitude of the 90° reference generator. It is obtained by using the 90° generator as both signal and reference.

K -- is a gain constant.

The additional A/D converter assemblies measure the following quantity.

$$C_p \text{ or } L_s = K \frac{V_s \text{ dc } Q}{V_r \text{ dc } Q}$$

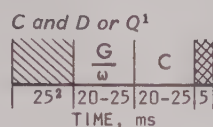
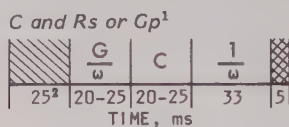
Where:

$V_s \text{ dc } Q$ -- A dc voltage proportional to the amplitude of the quadrature component (reactance) of the unknown. It is obtained by using the 90° generator as a reference.

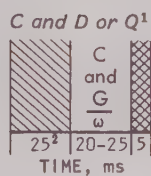
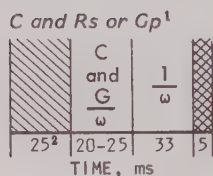
$V_r \text{ dc } Q$ -- A dc voltage proportional to the amplitude of the 90° reference generator. It is obtained by using the 90° generator as both signal and reference.

K -- is a gain constant.

These ratios provide the CPU with digital information proportional to the value of the selected measurement and offset voltages. The CPU subtracts the voltage offset from the actual measurement. Simultaneous measurement of the reactive and loss components of the unknown decrease the total measurement time as shown below.



Normal single cycle measurements



 Settling time and autozeroing period

 Final calculation period

¹ For Inductance functions, replace G/ω with R_s/ω and C with L

² Dependent on Range, see Settling Time Chart

Single cycle measurements with high speed option

A.7.4 Calibration

WARNING

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If this option is field installed, the following calibration must be performed. Periodic recalibration is described in Section 4 of the Model 296 and 296V manuals.

1. Connect stable capacitor as unknown. (Value not important but should be 10,000 counts or greater e.g., 10nF.)
2. Set instrument to measure capacitance.
3. Set to autorange.
4. Note reading in left display.
5. Turn off instrument.
6. Plug the A/D Linear assembly (Part No. 40702) into the location marked A/D SAR (17), see Figure A-1.

7. Plug the A/D Digital assembly (Part No. 40689) into the location marked OPTIONAL A/D (14), see Figure A-1.
8. Turn instrument on.
9. Repeat steps 2 and 3.
10. Adjust trimmer 2 on optional A/D (board 17, see Figure A-1) for same reading as step 4.

A.8 DC RESISTANCE MEASUREMENT OPTION

Model 296 normally applies an ac signal to the unknown, therefore the resistance measured is an ac quantity. The dc resistance measurement option allows dc resistance and ac inductance to be measured and displayed at the same time. With the dc resistance option circuit assembly installed, this function is programmed in the same manner as other front panel functions. Inductance is the only other function allowed in combination with dc resistance measurement and is automatically selected when the DC OHMS button is pressed. DC resistance display is shown by both the D and Ω indicators lighting. The dc resistance option increases resistance measurement range to 20M Ω . Resistance alone is measured on the 20M Ω range and the lefthand display blinks.

A.8.1 Specifications

RANGE NO.	0	1	2	3	4	5	6	7	8	9
DC RESISTANCE RANGE FULL SCALE			1.9999 Ω	19.999 Ω	199.99 Ω	1.9999 k Ω	19.999 k Ω	199.99 k Ω	1.9999 M Ω	19.999 M Ω
ACCURACY $\pm$ (% OF READING) (+ COUNTS)	$\pm[0.05\% (0.02\% \text{ Typical}) + 2 \text{ Counts}] \pm 1 \text{ m}\Omega$									$\pm[0.5\% (0.2\% \text{ Typical}) + 5 \text{ Counts}]$
DC CURRENT TO UNKNOWN I _x			20 mA		2 mA	200 μ A		20 μ A	2 μ A	0.2 μ A
RANGE NO.	0	1	2	3	4	5	6	7	8	9
L BRIDGE RANGE 1 kHz FULL SCALE			199.99 μ H	1.9999 mH	19.999 mH	199.99 mH	1.9999 H	19.999 H	199.99 H	
			1999.9 μ H	19.999 mH	199.99 mH	1999.9 mH	19.999 H	199.99 H	1999.9 H	
AC TEST HI CURRENT			100 mA		10 mA	1 mA	100 μ A	10 μ A	1 μ A	
SIGNAL LO CURRENT			10 mA		1 mA	100 μ A	10 μ A	1 μ A	0.1 μ A	
ACCURACY 1 kHz $\pm$ (% READ) LO CURRENT			$\pm(0.1\% + 0.005\%)$						$\pm(0.5\% + 0.5\%)$	
(% FULL HI CURRENT SCALE) 120 Hz			$\pm(0.1\% + 0.01\%)$						$\pm(0.1\% + 0.025\%)$	$\pm(0.5\% + 0.1\%)$
LO CURRENT			$\pm(0.1\% + 0.025\%)*$						$\pm(0.1\% + 0.05\%)$	$\pm(0.5\% + 0.25\%)$

*Multiply by 2 for 120 Hz or single cycle measurement

A.8.2 Hardware Included

DC Resistance Circuit Assembly

Part No.
42596

The following instructions are for installing DC Resistance Option Kit (Part No. 42536).

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TO AVOID DAMAGE TO CIRCUITRY, TURN POWER OFF WHILE PLUGGING IN OR REMOVING CIRCUIT ASSEMBLIES.

-

4. Install mercury relays in sockets noting "up" marking on relay. Gently tap relay to shake down mercury before installing.

5. Install threaded spacer, provided, on screws projecting through the protection board, (see Figure A-8).
6. Install lexan plastic piece and lock washer on spacers using screws provided (see Figure A-8). This prevents relays from vibrating loose.

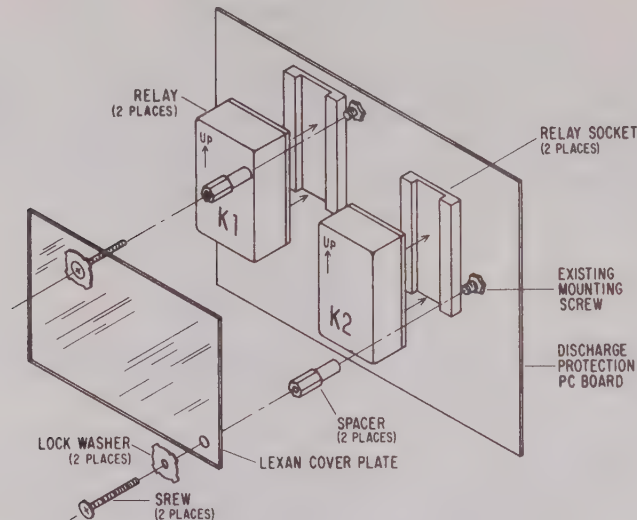


Figure A-8.

7. Turn instrument on and allow 0.5 hour warm-up time.
8. Perform calibration.
9. Replace instrument covers before operating.

A.8.4 Operation

The measurement cycle for dc resistance measurement is illustrated in Figure A-9. DC resistance is measured first, then the ac inductance measurement is performed. The dc measurement is composed of two measurements, with the detector polarity switched after the first, to cancel offset errors. Normal averaging measurement takes place for the inductance part of the measurement cycle. Depending on the range and accuracy required, the measurement time can be reduced by programming less settling time. Another reduction in time may be achieved by eliminating the averaging on the inductance measurement, see Table 2-3 and Section 2.3.9 of Model 296 manual for information on how to eliminate averaging.

When the dc resistance option PC board is installed, zero adjustments must be set as described in Section 4.1.1 of Model 296 manual. Periodic recalibration is described in Section 4.1.2.6 of Model 296 manual.

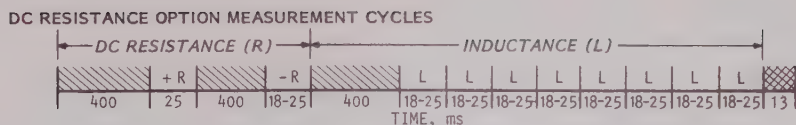


Figure A-9.

PIA (U9) interfaces the dc resistance measuring circuitry to the microprocessor. It provides control of amplifier inputs, gains, standard resistors and drive voltages (see Table A-8 for PIA OUTPUT CODES). The PIA also sends a relay drive signal to the protection circuit assembly that works to select inductance or dc resistance measurements.

DC Resistance Converter 42596

RANGE NO.	PIA OUTPUTS - MC6820								
	PB 0	PB 1	PB 2	PB 3	PB 4	PB 5	PB 6	PB 7	I
1.9999 Ω 0	0	1/0	0	0	0	1	1	0	20mA
19.999 Ω 1	0	1/0	0	0	0	1	0	1	20mA
199.99 Ω 2	0	1/0	0	1	1	0	0	1	2mA
1.99999k Ω 3	0	1/0	0	1	0	1	0	1	0.2mA
19.999k Ω 4	0	1/0	0	1	0	1	0	0	0.2mA
199.99k Ω 5	0	1/0	1	0	1	0	0	0	20mA
1.9999M Ω 6	0	1/0	1	0	0	1	0	0	2 μ A
19.999M Ω 7	0	1/0	1	1	0	1	0	0	0.2 μ A
	Option Select	+/-	Range Resistor		V Ref Ratio		Det Gain		
	0=DCR 1=AC LRC	0=- 1=+	00=10 Ω 01=1k Ω 10=100k Ω 11=1M Ω		01=X0.1 10=X1		00=X0.5 01=X0.5 10=X0.50		

1 = a high logic level.

Table A-8. PIA Output Codes

DC current drive to the unknown is initiated when a 2VDC reference voltage is applied to selectable, series resistor networks (see Figure A-10). Integrator U1 senses any voltage difference at a tap between the series resistors and produces a current output proportional to the difference. This output current flows through a stabilizing resistor (R_s) and the unknown resistor (R_x) to the input of amplifier U2. Variable gain amplifier U2 produces a voltage output of a polarity and magnitude that when applied to the series resistor network it drives the input of U1 to a null.

Variable gain detector circuitry U3, U4, U5 and U6 sense the voltage across the unknown to produce an output that is proportional to the unknown value. This circuitry cancels thermal and offset voltages by making two measurements at reversed polarity for each measurement cycle.

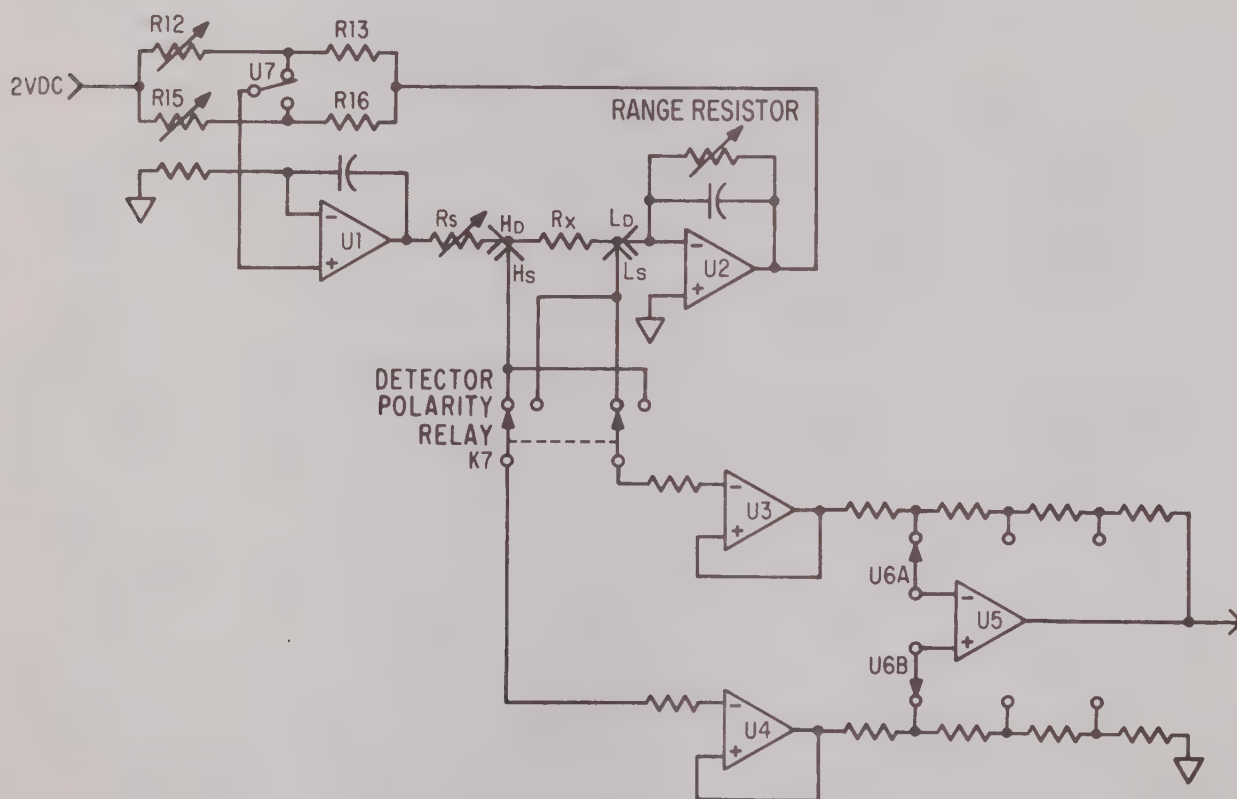


Figure A-10.

A.8.5 Calibration

WARNING

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CAUTION

WHEN PERFORMING ANY CALIBRATION OR MAINTENANCE OPERATION, DO NOT REMOVE OR REPLACE CIRCUIT BOARDS WHILE THE POWER IS TURNED ON.

A.8.5.1 Zero Adjustments

NOTE: See Figure A-1 for trimmer locations.

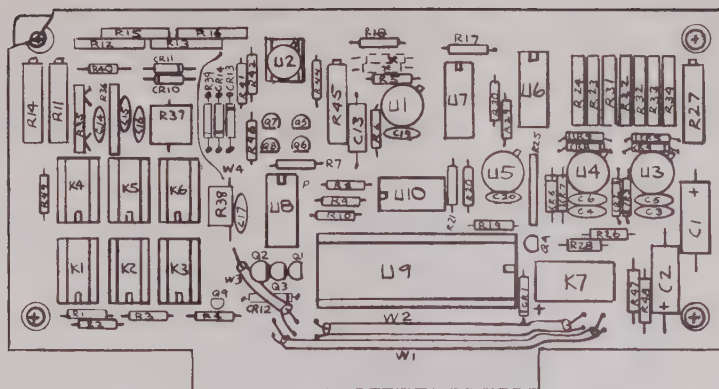
1. Turn power on.
2. Let unit autorange.
3. Push four times to 1.9999 μ F range.
4. Separate leads for minimum capacitance (approximately 4 inches).
5. Adjust trimmer 1 on board 5 for zero on left display.
6. Adjust trimmer 1 on board 7 for zero on right display.
7. Set to LO frequency.
8. Adjust trimmer 2 on board 5 for zero on left display.
9. Adjust trimmer 2 on board 7 for zero on right display.
10. Return to HI frequency.
11. Set to autorange and let it range to lowest capacitance range.
12. Adjust front panel G ZERO and C ZERO.

A.8.5.2 DC Resistance Adjustment

NOTE: See Figure A-11 for trimmer locations. Calibration steps 4 through 16 have been performed at the factory and need only be repeated if a component has been replaced.

1. Turn instrument power off.
2. Plug dc resistance card into extender board, then into OPTIONAL A/D socket (see Figure A-1).
3. Turn instrument power on.
4. Short unknown leads together.
5. Set instrument to dc resistance mode.
6. Set to autorange.
7. Connect either end of R26 and R28 to ground. *(two jumpers total)*
8. Connect millivolt meter to bottom end of R25 (output of U5).
9. Adjust R27 for zero $\pm 20\text{mV}$ on meter. *(equal swing from zero)*
10. Remove clip leads of step 4.
11. Allow 15 minutes warm-up.
12. Set standard to $1\text{k}\Omega$.
13. Set R14 to center of range and select R43 for 10,000 counts ± 30 counts on right display.
14. Solder R43 in.
15. Remove extender board and plug resistance card directly into socket.
16. Connect standards and adjust as follows to ± 2 counts accuracy.

STD	ADJ
$1\text{k}\Omega$	R14
100Ω	R11
$10\text{M}\Omega$	R45
18. Check each range at 10,000 and 19,000 counts for $\pm 0.02\%$, ± 0.5 milliohm accuracy. Might have to use RS925 for the 19,000 counts. Do not use RS925 for resistance checks below 1Ω .



* R43 1 POSITION
OR THE OTHER

Figure A-11.

APPENDIX B

OPTIONS PARTS LISTS AND CIRCUIT ASSEMBLIES

B.1 IEEE Interface Option Circuit Assembly (Part No. 42132)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C2	Capacitor, 100 μ F, 25V	13683
Q1-Q12	Transistor, 2N3904	18751
R1-R5	Resistor, 6.8k Ω , 1/4W Carbon	13930
R6-R8	Resistor, 4.7k Ω , 1/4W, 10%	13927
S1, S2	Switch, SPST, DIP, Rocker	41519
U1, U2	IC, 6820, PIA	41292
U3-U16	IC, MCT6, Optoisolator	24008
U17, U25	Resistor, 1k Ω , DIP	20700
U18	Resistor, 3.3k Ω , DIP	22947
U19	Resistor, 470 Ω , DIP	20795
U21	Resistor Network, 470 Ω and 3.3k Ω	43000
U22-U24	IC, MC3446, Quad Interface Bus Tran	42704
U26	IC, 7407, TTL Open Coll Hex Inverter	24076
W1-W5	Wire	50203
	Shield, PCB	41469
	Socket, 8 Pin DIP	22410
	Socket, 40 Pin DIP	41342

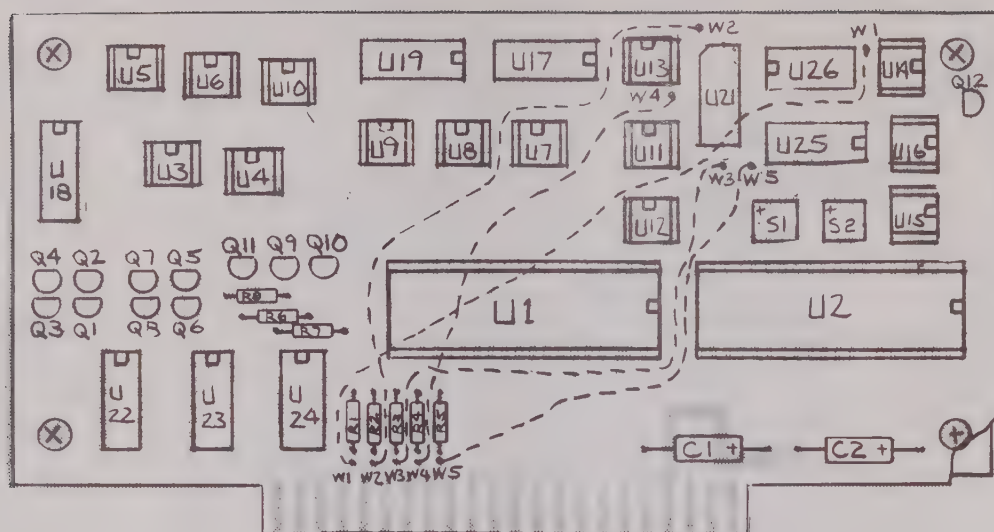
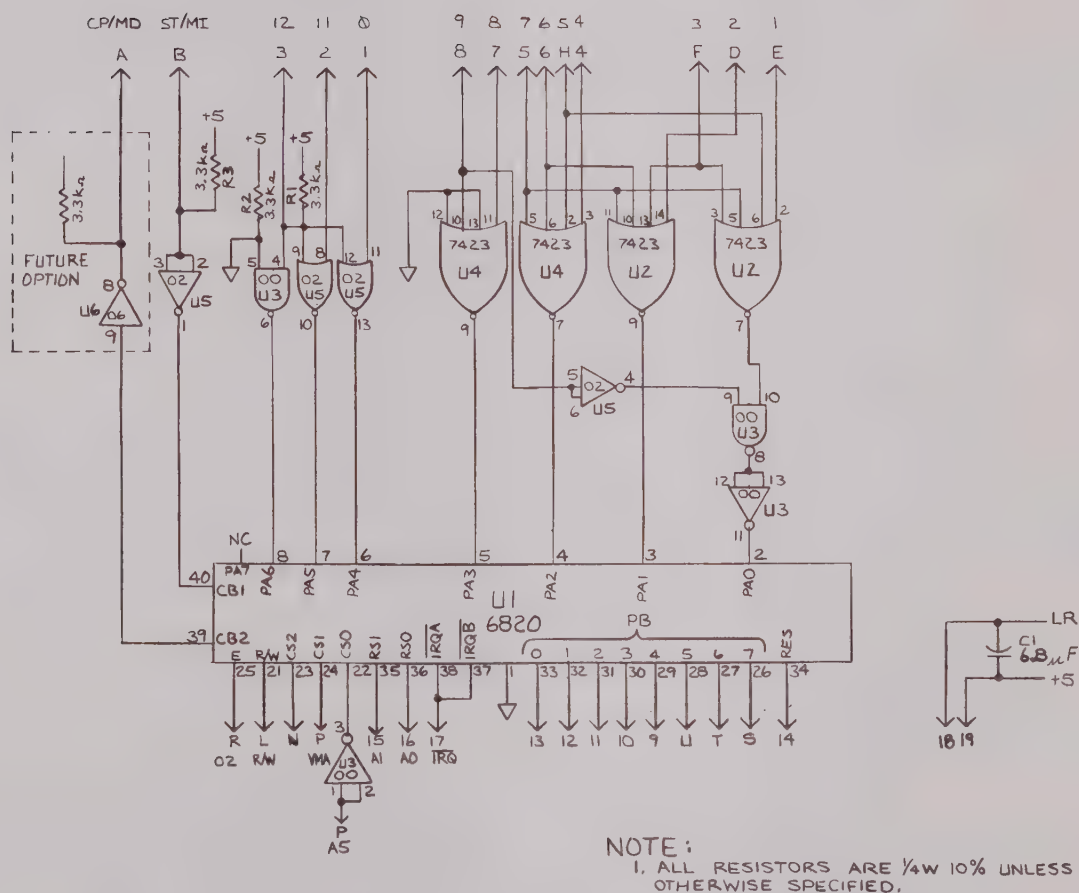


Figure B-1. Part No. 42132

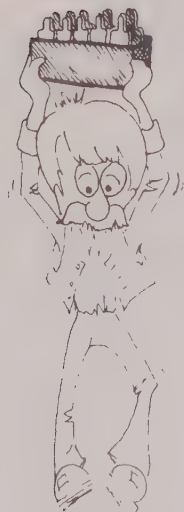


B.4 Optional Interface Circuit Assembly, Engineered Automation,
(Part No. 42073)

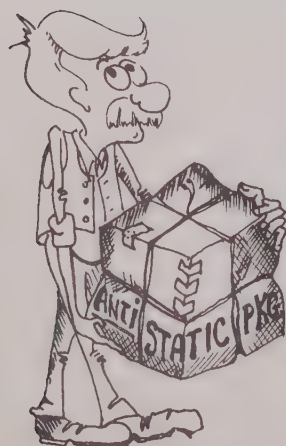
<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 100 μ F, 25VDC, Elect	13683
C2-C5	Capacitor, 6.8 μ F, Tant	43792
K1-K10, K12	Relay, GB821A-4	24804
K14	Optical Isolator, TIL119	44224
R9	Resistor, 120 Ω , 10%, 1/4W	13908
R10, R11	Resistor, 3.3k Ω , 10%, 1/4W	13926
U1	IC, 6820, MOS, 40 Pin	41292
U2-U5	IC, 7433	20718
U6	Resistor Pack, 3.3k Ω , DIP	22947
U7	Optical Isolator, 4N28	20674
W1-W8	Wire, Bus, #22	06091
	Socket, 14 Pin DIP	19189
	Socket, 40 Pin DIP	41342

PROTECT AGAINST ELECTROSTATIC DISCHARGE

In this instrument there are MOS and FET semiconductors, which can be damaged by electrostatic discharge during handling. The following precautionary procedures are recommended to minimize this possibility.



HANDLE DEVICES BY THE BODY. DO NOT TOUCH THE DEVICE LEADS.



USE ANTI-STATIC PACKAGING FOR HANDLING AND TRANSPORT

KEEP PARTS IN MANUFACTURER'S PROTECTED CONTAINERS



BE SURE YOUR SOLDERING IRON TIP IS GROUNDED AND DO NOT USE SOLDER-SUCKERS THAT ARE NOT ANTI-STATIC PROTECTED



DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES



AVOID HANDLING WHENEVER POSSIBLE

DO NOT SLIDE STATIC SENSITIVE DEVICES OVER ANY SURFACE AND AVOID PLASTIC, VINYL AND STYROFOAM IN WORK AREAS



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WARRANTY OF QUALITY

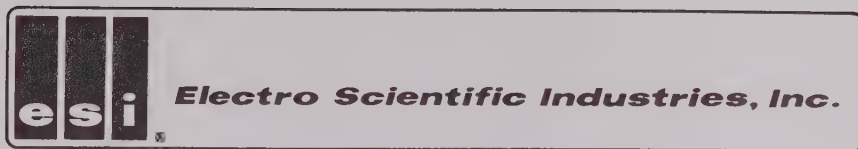
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1. Two years for components and instruments utilizing passive circuitry. One year on repairs of out-of-warranty items.
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During the in-warranty periods, we will service or, at our option, replace any device that fails in normal use to meet its published specifications. Batteries, tubes and relays that have given normal service are excepted. Special systems will have warranty periods as listed in their quotation.

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The manufacture and final calibration of all ESI instruments are controlled by the use of ESI reference and working standards and testing apparatus in accordance with established procedures and with documented results. (Reference MIL-C 45662)

Final calibration of this instrument was performed with reference to the mean values of the ESI reference standards or to ratio devices that were verified at the time and place of use.

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4.1.4 Calibration Summary

Calibration Summary

Section 4.1.3 Step No.	MODEL 296 SETUP				ADJUSTMENT			
	Range No.	Function	Freq	Voltage	Unknown Value	Trimmer No.	Board No.	Test Point
3	8	F S	HI	HI	Open	1	1	OSC OUT
7	8	F S	LO	HI	Open	2	1	Tsf
14	8	F S	HI	HI	Open	3	16	1
22	8	F S	HI	HI	Open	1	2	4
24	8	F S	HI	HI	Open	2	2	5
26	8	F S	HI	HI	Open	3	2	1
26	8	F S	HI	HI	Open	4	2	1
29	8	F S	LO	HI	Open	Check Steps 22,24,26	2	1
36	8	F S	HI	HI	Open	2	3	5
38	8	F S	LO	HI	Open	Check step 36	3	5
43	4	F S	HI	HI	Open	1	5*	LT DSP
44	4	F S	HI	HI	Open	1	7*	RT DSP
46	4	F S	LO	HI	Open	2	5*	LT DSP
47	4	F S	LO	HI	Open	2	7*	RT DSP
50	8	F S	HI	HI	Open	G	DSP	RT DSP
50	8	F S	HI	HI	Open	C	DSP	LT DSP
52	8	F S	HI	LO	Open	1	3	LT DSP
Repeat steps 50 through 52.								
53	AUTO	F H D	HI	HI	1.5nF	7	6	RT DSP
61	AUTO	F D	HI	HI	1.5nF	8	6	RT DSP
63	AUTO	F D	HI	HI	1.5nF	8	6	RT DSP
67	AUTO	F H D	LO	HI	1.5nF	5	6	RT DSP
69	AUTO	F D	LO	HI	15nF	9	6	RT DSP
73	AUTO	F J	HI	HI	15nF	D	6	RT DSP
76	AUTO	F D	HI	HI	150nF	C	6	RT DSP
77	AUTO	F D	HI	HI	1.5nF	B	6	RT DSP
81	AUTO	F H D	HI	HI	1ka ±0.01%	10	6	RT DSP
82	AUTO	F S	HI	HI	1ka ±0.01%	8	6	RT DSP
83	AUTO	F H S	HI	HI	1ka ±0.01%	3	6	LT DSP
85	AUTO	F H S	LO	HI	1ka ±0.01%	1	6	LT DSP
87	AUTO	F S	LO	HI	1ka ±0.01%	6	6	RT DSP
90	AUTO	F L	HI	HI	1nF	4	6	LT DSP
93	AUTO	F I	HI	HI	1nF	7	6	RT DSP
95	AUTO	F U	LO	HI	1nF	2	6	LT DSP
96	AUTO	F D	LO	HI	1nF	5	6	RT DSP
Repeat steps 78 through 96 until readings are within ±2 counts of nominal value								
100	AUTO	F H S **	HI	HI	100	A	6	LT DSP
101	AUTO	F H S **	HI	HI	100	3	5	LT DSP
108	AUTO	F D	HI	HI	1nF	2	8	RT DSP
111	AUTO	F D	HI	LO	100pF	2	4	RT DSP
113	AUTO	F D	HI	LO	100pF	3	8	RT DSP
117	0	F D	HI	LO	Open	1	4	RT DSP
118	AUTO	F U	HI	LO	100pF	1	3	RT DSP
125	AUTO	H D	LO	HI	100pF or less	L	DSP	LT DSP
125	AUTO	H D	LO	HI	100pF or less	R	DSP	RT DSP
131	6	TANδ	HI	HI	1nF	1	18	LT DSP

*Front Phase Rectifier PC board adjusts the left display.

Rear Phase Rectifier PC board adjusts the right display.

**Alternate between F and S functions and H and A functions

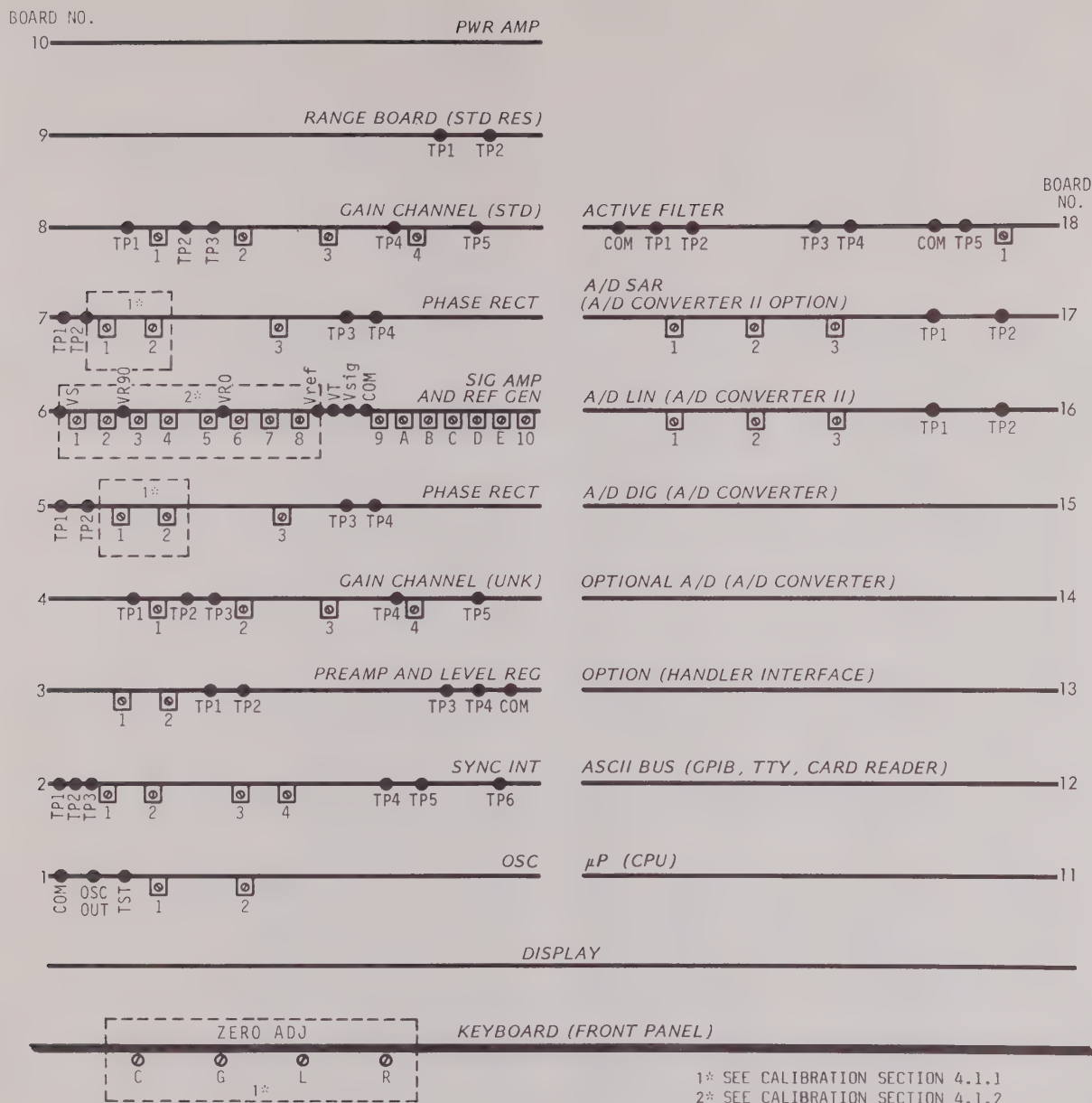


Figure 4-1. Model 296 PC Board, Trimmer and Test Point Locations



Display and Control Check

1. Turn the instrument OFF then ON again. After autoranging, the front panel indicators should display:

+ 00.00 p Fp + .0000 μ S

- A. If the displays are lit and indicating the proper engineering units, but read something other than zero--go to Calibration Section 4.1.1 and perform the zero adjustments. If the displays will not adjust to zero, check the analog circuitry on the display PC board.
 - B. If the displays are blank, check the digital circuitry on the Display PC board and/or the CPU PC board.
 - C. If the displays are blinking (overload indication) or some LEDs not lit, go to the next step.
2. Check all display indicators. Follow Table 4-1 in the sequence indicated. If any display does not appear as indicated, check the digital circuitry on the display PC board and/or the CPU PC board.
 3. Check the measurement (relay) control signals. Follow Table 4-2 in the sequence indicated. If any signal does not appear as indicated, check the digital circuitry on the Display PC board and/or the CPU PC board.
 - A. Turn power OFF.
 - B. Place the Display PC board on extenders.
 - C. Turn power ON.

5.2 A/D CONVERTER CIRCUIT ASSEMBLY (Part No. 40689)

CIRCUIT NO.	DESCRIPTION	ESI PART NO.
C1	Capacitor, 20pF, 600V, Poly	20926
C2	Capacitor, 6.8μF, 35V, Tant	25339
C3-C5	Capacitor, 0.01μF, 50V, Disc	12144
R1	Resistor, 560Ω, 10%, 1/4W, CC	13916
R2	Resistor, 820Ω, 10%, 1/4W, CC	13919
U1	IC, 6820	41292
U2	IC, 7404	20695
U3, U9	IC, 7473	20613
U4-U7	IC, 74193	20677
U8	IC, 7400	20600
Y1	Crystal, 3.93216MHz (60Hz)	24399 (Std)
	Crystal, 3.2768MHz (50Hz)	24540 (Opt)
	Socket, Crystal	24444
	Socket, IC 40 Pin	41342

NOTES:
1) ALL RESISTORS ARE 1/4W, 10% UNLESS OTHERWISE SPECIFIED.
2) ALL CAPACITORS ARE MEASURED IN μF UNLESS OTHERWISE SPECIFIED.

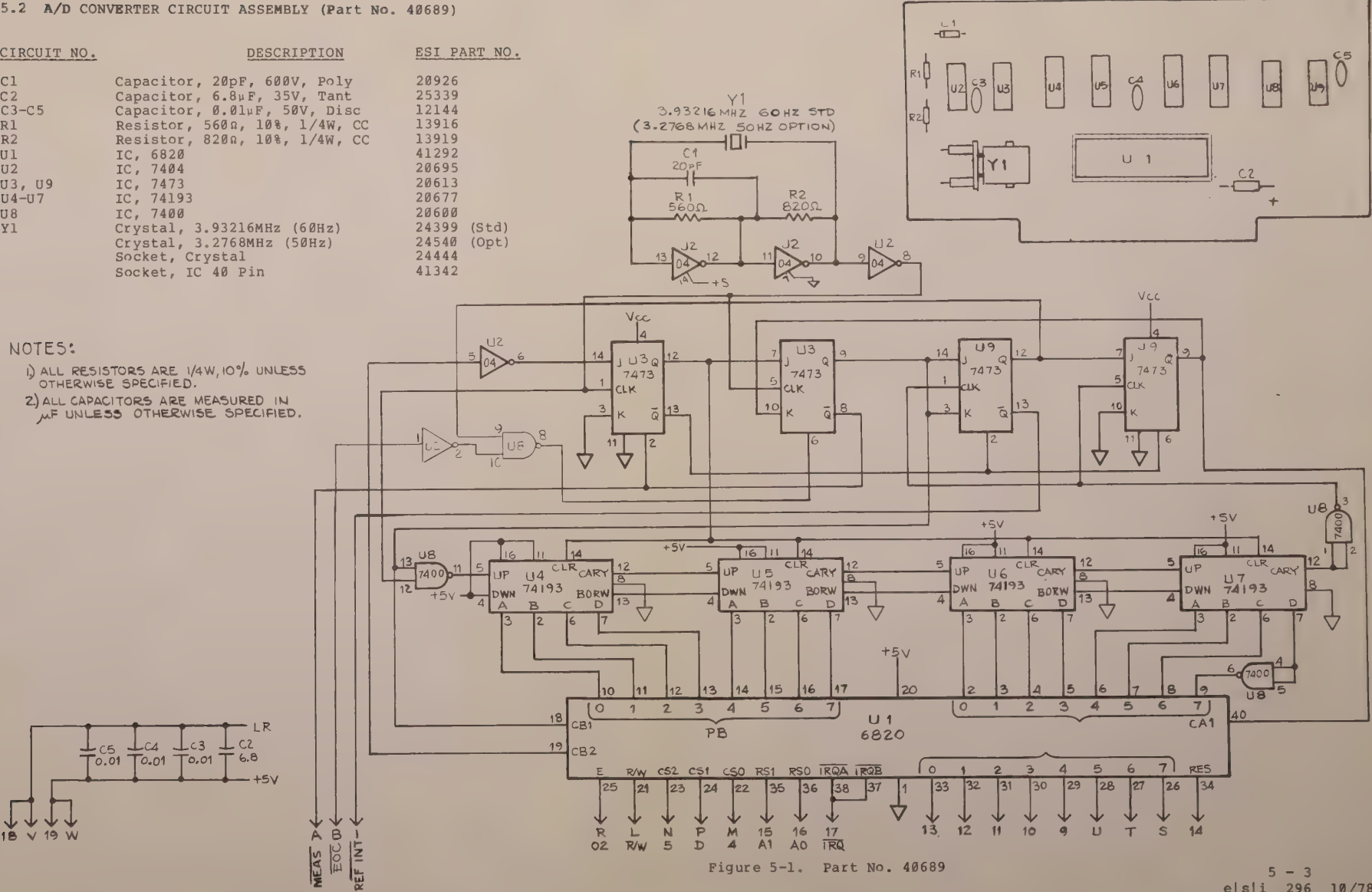


Figure 5-1. Part No. 40689

5.3 A/D CONVERTER II CIRCUIT ASSEMBLY (Part No. 40702)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C2	Capacitor, 0.033 μ F, 400V, Poly	26097
C3	Capacitor, 4pF, 500V, Disc	02126
C4-C15, C22	Capacitor, 0.01 μ F, 50V, Disc	12144
C16-C20	Capacitor, 6.8 μ F, 35V, Tant	25339
C21	Capacitor, 0.05 μ F, 50V, Disc	12116
C24	Capacitor, 500pF, 50V, Disc	12043
CR1	DIODE 1N825	20868
CR2, CR4, CR5	Diode 1N914A	12356
Q1, Q2	Transistor, 2N3906	18754
R3	Resistor, 3.9k Ω , 0.01%, ESI Q	42875
R6	Resistor, 2k Ω , 0.01%, ESI Q	42630
R8	Resistor, 100 Ω , 1%, 1/4W	21720
R10	Resistor, 1k Ω , 0.01%, ESI Q	42631
R11	Resistor, 124k Ω , 1%, 1/4W, Film	21751
R12	Potentiometer, 20k Ω	21199
R13	Resistor, 470 Ω , 10%, 1/4W	13915
R14	Resistor, 220k Ω , 10%, 1/4W	13949
R15	Resistor, 100 Ω , 10%, 1/4W	13907
R16, R17, R19, R21, R22, R24	Resistor, 4.7k Ω , 10%, 1/4W	13927
R18, R20, R23	Resistor, 1k Ω , 10%, 1/4W	13920
R25	Resistor, 6.8k Ω , 10%, 1/4W	13930
R26-R30	Resistor, 10 Ω , 10%, 1/2W	02039
R31	Resistor, 750 Ω , 1%, 1/8W	25999
R32	Resistor, 16.9k Ω , 1%, 1/8W	25290
R33	Potentiometer, 100 Ω	26853
R34	Resistor, 8.45k Ω , 1%, 1/4W	83288
R35, R36	Resistor, 1%, 1/4W	Select
R37	Resistor, 10k Ω , 10%, 1/4W	13933
R38	Potentiometer, 200 Ω	12083
U1, U3	Op-Amp, 741K	21625
U2	Op-Amp, AD504J	20697
U4	CMOS Switch, 4066AE	41761
U5	Op-Amp, LF356	41473
U6	Op-Amp, 301A	20669
U7	Op-Amp, 311N	29544
U8	CMOS Gate, 4001AE	40842
U9	CMOS Switch, 4051AE	40841
U10	CMOS Switch, CD4053	20744
W1, W2	Wire	06091

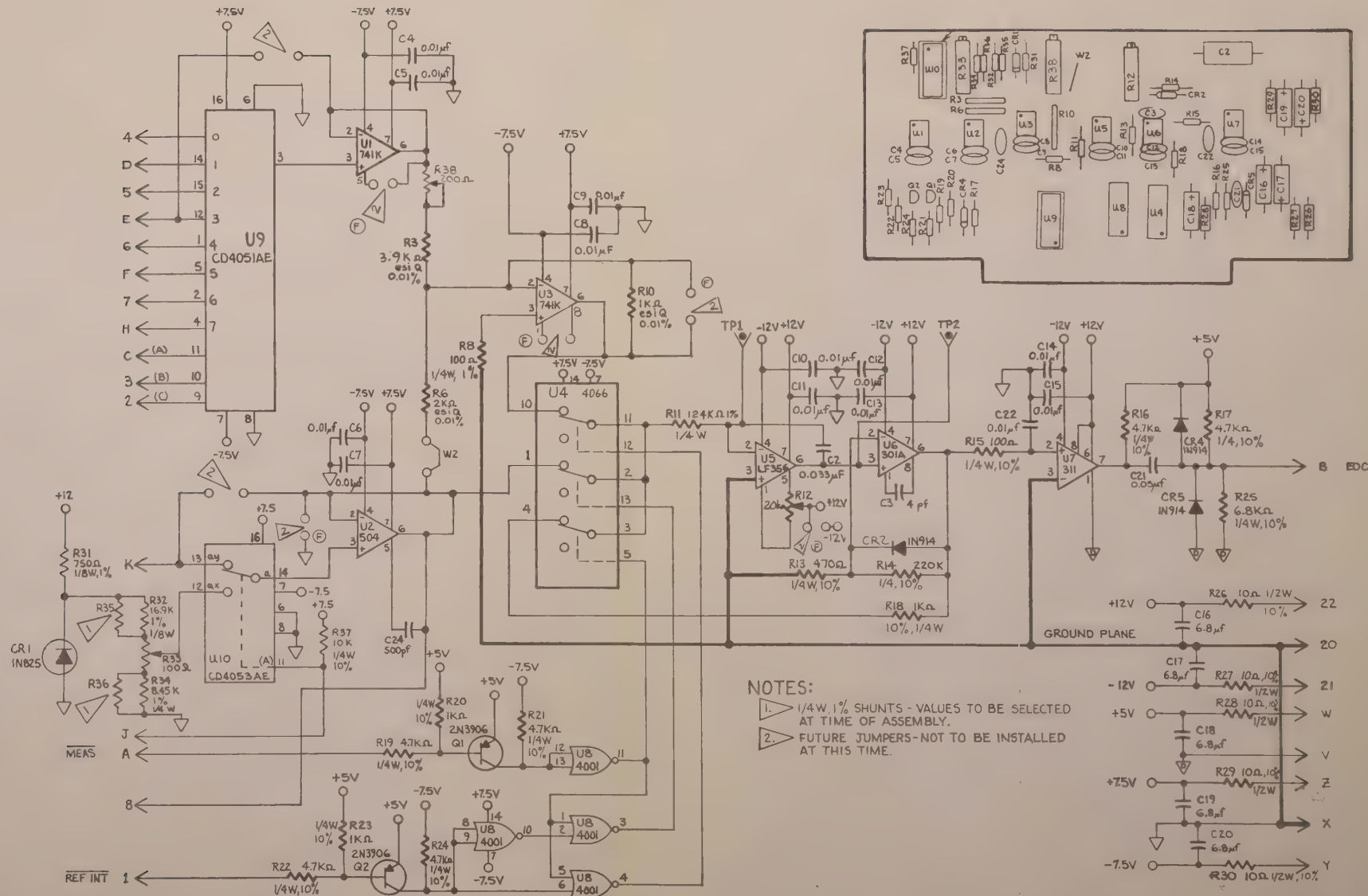
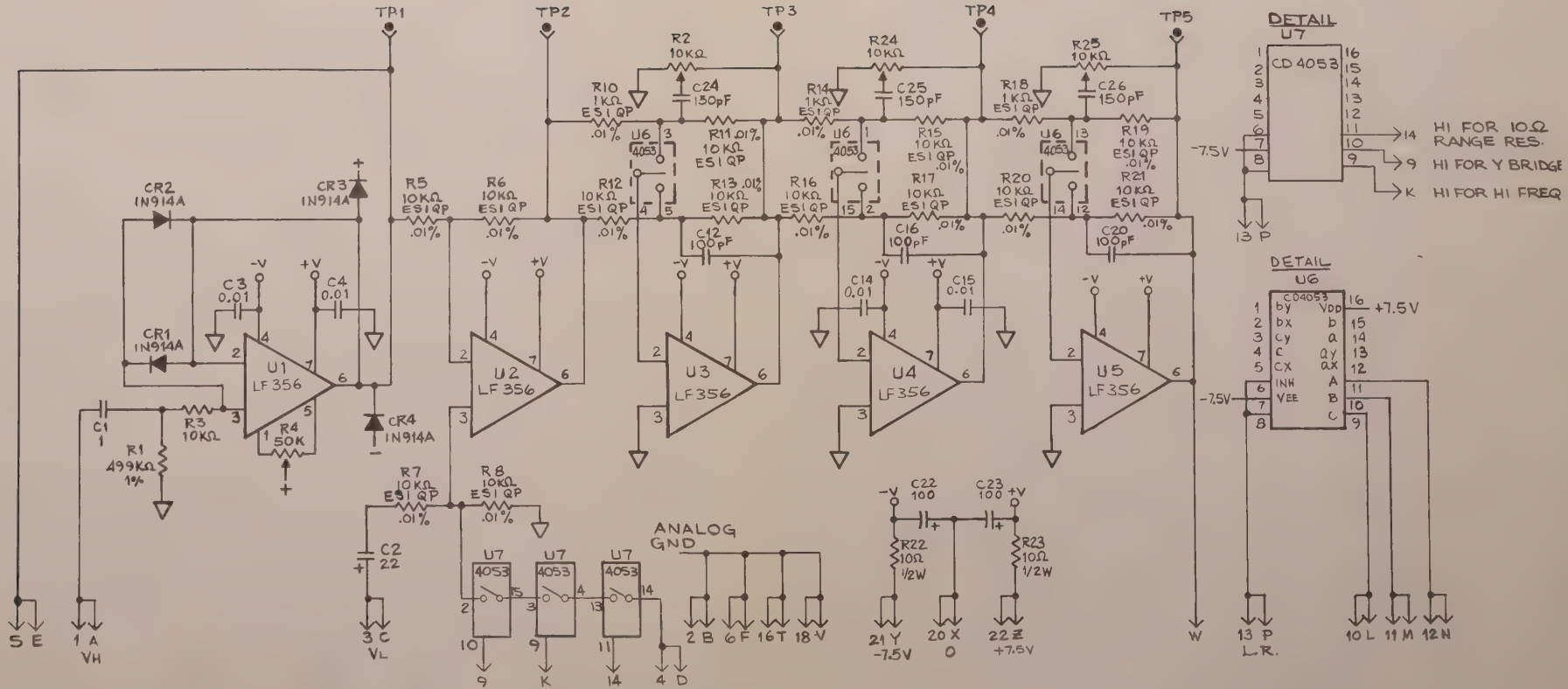


Figure 5-2. Part No. 40702

5.4 GAIN CHANNEL CIRCUIT ASSEMBLY (Part No. 40935)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 1 μ F, 200V, MMW	18843
C2	Capacitor, 22 μ F, 15V, Tant	18852
C3, C4, C14, C15,	Capacitor, 0.01 μ F, 50V, Disc	12144
C12, C16, C20	Capacitor, 100pF	18760
C24-C26	Capacitor, 150pF, 600V, Poly	29606
C22, C23	Capacitor, 100 μ F, 12V	06157
CR1-CR4	Diode, 1N914A	12356
R1	Resistor, 499k Ω , 1%, 1/8W	21757
R2, R24, R25	Potentiometer, 10k Ω	20145
R3	Resistor, 10k Ω , 10%, 1/4W	13933
R4	Potentiometer, 50k Ω	12091
R5-R8, R11-R13,		
R15-R17, R19-R21	Resistor, 10k Ω , 0.01%, ESI QB	41673
R10, R14, R18	Resistor, 1k Ω , 0.01%, ESI QP	41471
R22, R23	Resistor, 10 Ω , 10%, 1/2W	02039
U1-U5	Op-Amp, LF356	41473
U6, U7	IC, CD4053, Switch	20744
	Shield, PC Board	41469
	Socket, 8 Pin DIP	22410
	Socket, 16 Pin DIP	20860



- 1) ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED
- 2) ALL RESISTORS ARE 1/4W 10% UNLESS OTHERWISE STATED

Figure 5-3. Part No. 40935

5.5 PHASE RECTIFIER CIRCUIT ASSEMBLY (Part No. 40941)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C7	Capacitor, 25pF, 1kV, Disc	01924
C3-C6, C13, C14, C19, C20	Capacitor, 0.01μF, 50V, Disc	12144
C9	Capacitor, 0.01μF, 100V, Mylar	12260
C10, C11	Capacitor, 6.8μF, 35V, Tant	25339
C15, C16	Capacitor, 0.47μF, 50V	13653
C17, C18, C24, C25	Capacitor, 3μF, 50V	12358
C26, C27	Capacitor, 100μF, 12V	06157
CR2	Diode, 1N456	09155
K1	Relay, GB822A-2	26667
Q1	Transistor, 2N3702	12041
Q2-Q5	Transistor, 2N3704	12077
R1, R2, R7, R8	Resistor, 10kΩ, 0.01%, ESI QB	41673
R12, R28	Trimpot, 50kΩ	12091
R13	Resistor, 3.3kΩ, 10%, 1/4W	13926
R16	Resistor, 150Ω, 10%, 1/4W	13909
R17, R18	Resistor, 47Ω, 10%, 1/4W	13901
R19, R42	Resistor, 2.2kΩ, 10%, 1/4W	13924
R20, R23, R31, R34	Resistor, 20kΩ, 0.01%, ESI QB	23647
R21, R22, R24, R25, R32, R33, R35, R36	Resistor, 25kΩ, 0.01%, ESI QB	41676
R26, R51	Resistor, 15MΩ, 10%, 1/4W	13976
R27	Resistor, 5.6kΩ, 10%, 1/4W	13928
R29, R40, R43, R52	Resistor, 68Ω, 10%, 1/4W	13902
R30, R41	Resistor, 1kΩ, 10%, 1/4W	13920
R37, R47, R49, R50	Resistor, 27kΩ, 10%, 1/4W	13938
R38	Resistor, 15kΩ, 10%, 1/4W	13935
R39	Trimpot, 5kΩ	12092
R45, R46	Resistor, 10Ω, 10%, 1/2W	02039
R48	Resistor, 2.7kΩ, 10%, 1/4W	13925
U1, U2	Op-Amp 741K	21625
U3	Op-Amp, 311N	29544
U4, U5	Op-Amp, LM308A	23957
U6	Switch, CD4053	20744
U7	Op-Amp, 301A	20669
XK1	Socket, PC, 14 Pin DIP	19189
XU1-XU5, XU7	Socket, 8 Pin DIP, PC Mtg	22410
XU6	Socket, 16 Pin DIP, PC Mtg	20860
	Shield, PCB	41469

5.6 SIGNAL AMP AND REFERENCE GENERATOR CIRCUIT ASSEMBLY (Part No. 40943)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 220pF, 600V	29297
C2	Capacitor, 100pF, 500V	18760
C6, C7, C14, C15, C24, C25	Capacitor, 0.01μF, Disc, 50V	12144
C9, C10	Capacitor, 1μF, 200V	18843
C19, C31	Capacitor, 0.001μF, 1%, 500V	02157
C20, C21, C27, C28	Capacitor, 150pF, 600V	29606
C22, C23, C29, C30	Capacitor, 0.01μF, 1%	01929
C26	Capacitor, 0.002μF, 1%, 500V	02158
C32	Capacitor, Select	
CR1-CR6	Diode, 1N914A	12356
R1, R2, R8, R9	Resistor, 10kΩ, ±0.01%, ESI Q, ±5ppm/C°TC	41673
R3-R7, R11, R13	Trimpot, 20kΩ	21199
R10	Resistor, 1MΩ, ±10%, 1/4W	13960
R12	Resistor, 40.2kΩ, 1%, 1/8W	21746
R14	Resistor, 49.9kΩ, 1%, 1/4W	21747
R17, R18, R27, R33, R34	Resistor, 20kΩ, ±0.01%, ESI QB, ±5ppm/C°TC	23647
R19	Resistor, 40kΩ, ±0.01%, ESI QB, ±5%/C°TC	21112
R20	Trimpot, 1kΩ	18469
R21-R23, R29, R36-R40	Resistor, 200kΩ, 1%, 1/8W	41674
R24-R26, R31, R32	Trimpot, 10kΩ	20145
R28	Trimpot, 500Ω	12093
R30	Trimpot, 5kΩ	12092
R35	Resistor, 40.5kΩ, ±0.01%, ESI QB, ±5%/C°TC	43022
R41	Resistor, 15kΩ, 10%, 1/4W	13935
R42, R43	Resistor, 47kΩ, 10%, 1/4W	13941
R44	Resistor, 4990Ω, 1%, 1/4W	21737
U1-U7	OP Amp LF356	41473
U8-U10	Switch CD4053	20744
	Shield, PC Board	41469
	Socket, 8 pin DIP	22410

5.7 POWER AMP CIRCUIT ASSEMBLY (Part No. 41192)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1-C3, C5-C8	Capacitor, 0.01 μ F, 50V, Disc	12144
CR1-CR4, CR7-CR10		
CR13, CR14	Diode, 1N914A	12356
CR11, CR12	Diode, 1N4005	01779
K1, K5	Relay, Mercury Wetted	42634
K2-K4	Relay, GB821A-4	27841
Q1, Q7, Q13-Q16, Q18	Transistor, 2N3702	12041
Q2, Q8, Q17	Transistor, 2N3704	12077
Q3, Q9	Transistor, 2N3053	12232
Q4, Q10	Transistor, 2N4037	13590
Q5, Q11	Transistor, MJE371 (2N4918)	18753
Q6, Q12	Transistor, 2N4921	18752
R1, R5, R8, R10, R18, R21	Resistor, 1k Ω , 10%, 1/4W	13920
R2, R9, R11, R19, R20	Resistor, 100 Ω , 10%, 1/4W	13907
R3, R6, R12, R16	Resistor, 4.7 Ω , 10%, 1/4W	13890
R4, R7, R13, R17	Resistor, 1 Ω , 10%, 1/2W	12448
R14, R33	Resistor, 3.3k Ω , 1/4W, 10%	13926
R15, R34, R35	Resistor, 4.7k Ω , 10%, 1/4W	13927
R22	Resistor, 10k Ω , 10%, 1/4W	13933
R23	Resistor, 220k Ω , 10%, 1/4W	13949
R24	Resistor, 68 Ω , 10%, 1/4W	13902
R25, R26	Resistor, 27k Ω , 10%, 1/4W	13938
R28	Resistor, 2.7 Ω , 10%, 1/4W	13887
R31, R32	Resistor, 39 Ω , 10%, 1/4W	21219
U1	IC, CD4011	20725
	Shield, PCB	41469
	Socket, Relay, 14 Pin	19189
	Heat Sink	22859
	Washer, Mica, for Q5,6,11,12	41215

NOTE:

1. U1, PIN 7 = GND
U1, PIN 14 = +V
2. ALL RESISTORS ARE
1/4W, 10% ± RES IN ΩS, UNLESS
OTHERWISE NOTED.
3. ALL CAPS ARE IN μF,
UNLESS OTHERWISE
NOTED.

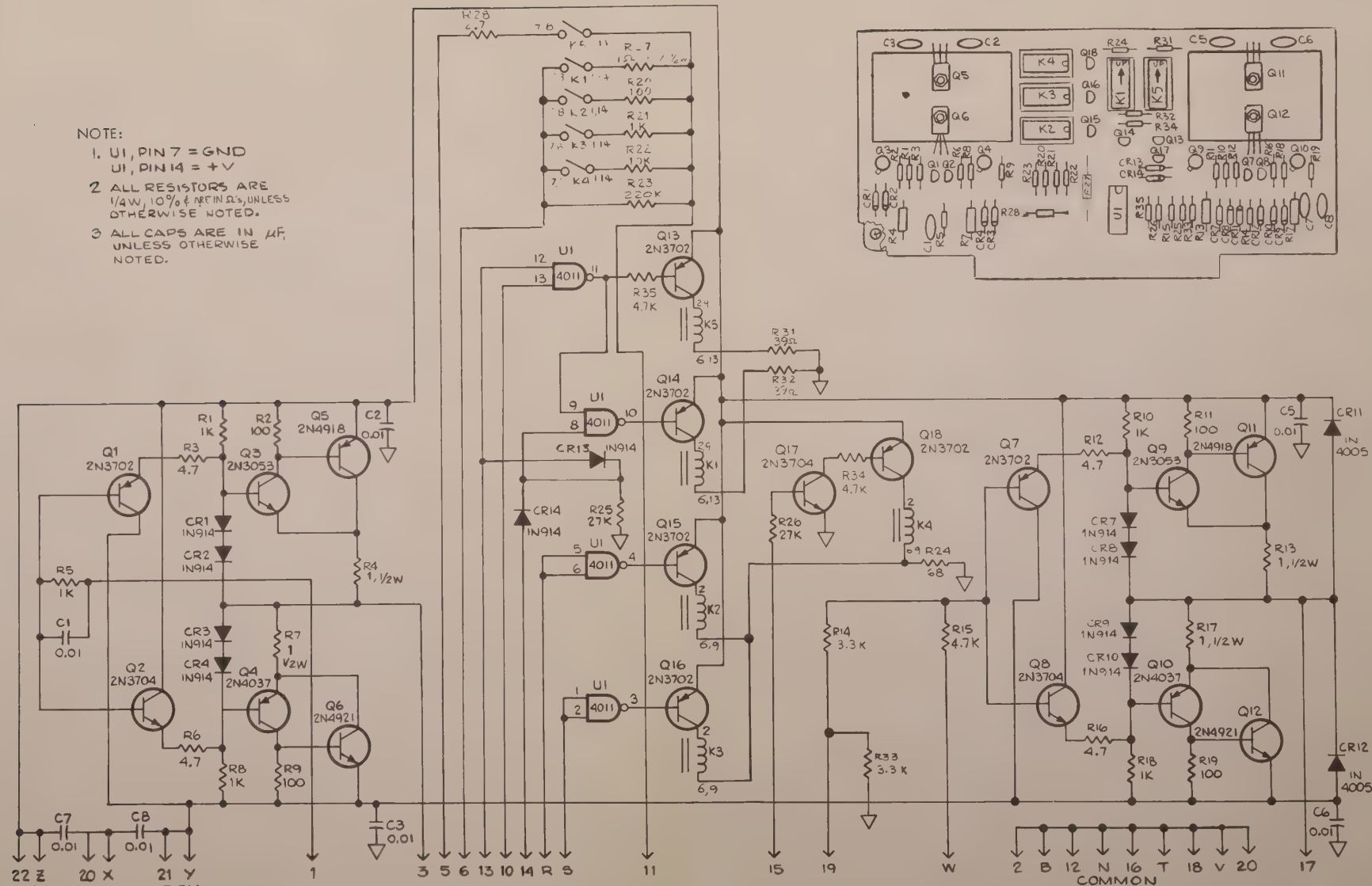


Figure 5-6. Part No. 41192

5.8 SYNCHRONOUS INTEGRATOR CIRCUIT ASSEMBLY (Part No. 41194)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C6, C8, C9	Capacitor, 0.1 μ F, 100V, WMF	06470
C2, C5, C10, C13	Capacitor, 0.001 μ F, 1kV, Disc	21215
C3, C11	Capacitor, 0.047 μ F, 200V, MMW	12239
C7	Capacitor, 25pF, 1kV, Disc	01924
C14, C15	Capacitor, 100 μ F, 12V	06157
R1, R3, R5, R11, R19, R21, R22, R24, R26, R32	Resistor, 100k Ω , 10%, 1/4W	13945
R2, R13, R23, R34	Resistor, 100 Ω , 10%, 1/4W	13907
R4, R15, R25, R36	Resistor, 10 Ω , 10%, 1/4W	13895
R6, R14, R16, R27 R35	Resistor, 47k Ω , 10%, 1/4W	13941
R7, R28	Trimpot, 100k Ω	21455
R9, R30	Resistor, 1M Ω , 10%, 1/4W	13960
R10, R31	Trimpot, 50k Ω	12091
R12, R33, R38, R20	Resistor, 270k Ω , 10%, 1/4W	20432
R17	Resistor, 220k Ω , 10%, 1/4W	13949
R18	Resistor, 330k Ω , 10%, 1/4W	13951
R37	Resistor, 33k Ω , 10%, 1/4W	13939
R39, R40	Resistor, 10 Ω , 10%, 1/2W	02039
R41, R42	Resistor, 470k Ω , 1/4W	13955
U1, U2, U4, U5, U8, U9, U11, U12	IC, 3080 CDA	20723
U3, U6, U7, U10	IC, 741 Op-Amp	20668
	Shield, PC Board	41469

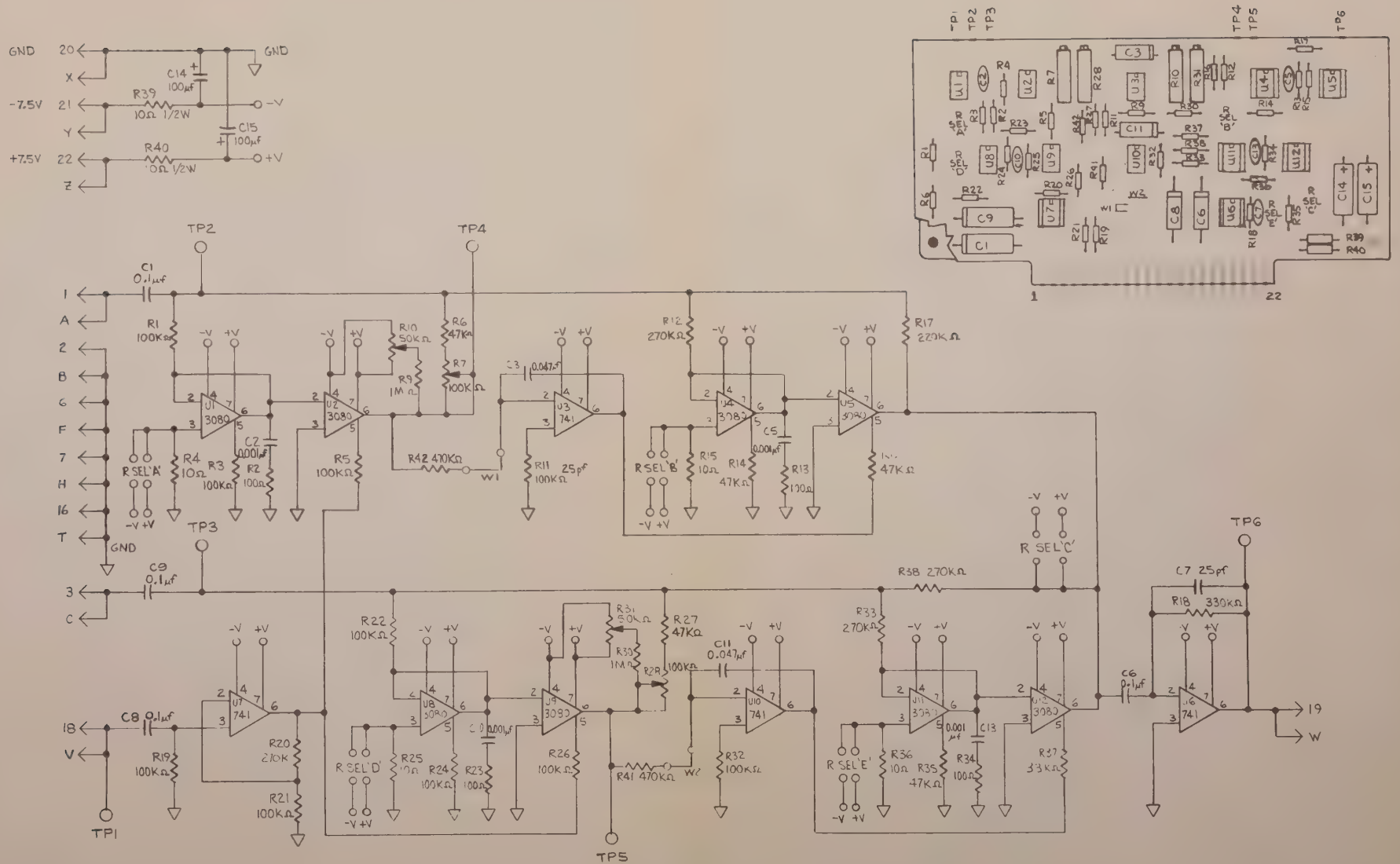
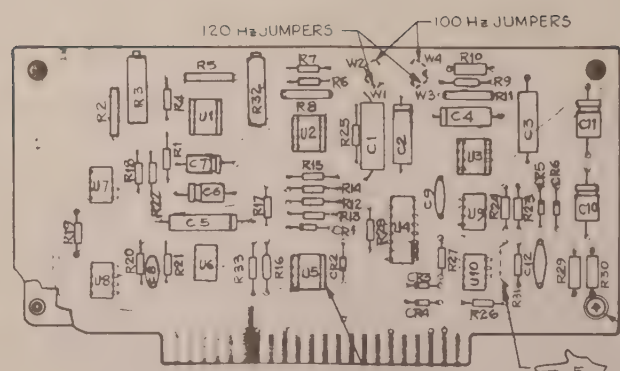


Figure 5-7. Part No. 41194

5.9 OSCILLATOR CIRCUIT ASSEMBLY (Part No. 41196)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C3	Capacitor, 0.01 μ F, 1%, Mica	01929
C2, C4	Capacitor, 0.1 μ F, 100V	12139
C5	Capacitor, 0.047 μ F, 100V, WMF	01776
C6, C7	Capacitor, 15 μ F, 12V	09916
C8	Capacitor, 0.001 μ F, 1kV, Disc	21215
C9, C12	Capacitor, 0.1 μ F, 100V, Disc	24395
C10, C11	Capacitor, 100 μ F, 12V	06157
CR1-CR4, CR5, CR6	Diode, 1N914A	12356
R1, R26, R28	Resistor, 10k Ω , 10%, 1/4W	13933
R2, R5	Resistor, 10k Ω , 0.02%, ESI QP	23613
R3	Trimpot, 20k Ω	21199
R4	Resistor, 220k Ω , 10%, 1/4W	13949
R6	Resistor, 15k Ω , 1%, 1/4W	21198
R7, R10	Resistor, 78.7k Ω , 1%, 1/4W	13166
R8, R11	Resistor, 16k Ω , 0.02%, ESI QP	41466
R9	Resistor, 15.8k Ω , 1%, 1/4W	21742
R12, R13, R15, R23, R24	Resistor, 10k Ω , 1%, 1/4W	21740
R14	Resistor, 20k Ω , 1%, 1/4W	21743
R16	Resistor, 63.4k Ω , 1%, 1/4W	21748
R17, R19, R20	Resistor, 39k Ω , 10%, 1/4W	13940
R18, R22, R31	Resistor, 100k Ω , 10%, 1/4W	13945
R21	Resistor, 100 Ω , 10%, 1/4W	13907
R25	Resistor, 150k Ω , 10%, 1/4W	13947
R27	Resistor, 6.8k Ω , 10%, 1/4W	13930
R29, R30	Resistor, 10 Ω , 10%, 1/2W	02039
R32	Trimpot, 2k Ω	12084
R33	Resistor, Select	
U1-U3, U5, U6, U9, U10	Op-Amp, 741	20668
U4	Switch, CD4053	20744
U7, U8	Op-Amp, 3080	20723
W1-W4	Wire	
	Shield, PCB	41469
	Socket, 8 Pin DIP	22410



5 - 17

5.10 ACTIVE FILTER CIRCUIT ASSEMBLY (Part No. 41221) (Old)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C9, C17, C25	Capacitor, 1 μ F, 200V	18843
C4, C12, C20, C28	Capacitor, 0.47 μ F, 100V	13238
C5, C7, C8, C13, C15, C16, C21, C23, C24, C29, C31, C32	Capacitor, 0.01 μ F, 50V, Disc	12144
C10, C26	Capacitor, 0.1 μ F, 200V	12121
C11, C27	Capacitor, 0.047 μ F, 200V	12239
C33, C34	Capacitor, 200 μ F, 15V	15838
R1, R2, R6, R7, R11, R12, R16, R17	Resistor, 15k Ω , 1%	21198
R5, R10, R15, R20	Resistor, 31.6k Ω , 1%, 1/4W	21745
R21, R22	Resistor, 10 Ω , 10%, 1/2W	02039
U2, U4, U6, U8	Op-Amp, 741K	21625
U3, U7	IC, CD4053	20744
W1-W4	Wire	
	Shield, PCB	41469
	IC Socket, 8 Pin	22410

NOTES:

1. * ARE THE LINES OUTSIDE OF FOIL
2. ALL RESISTOR VALUES ARE IN OHMS
3. ALL RESISTORS ARE 1/4 W 10% UNLESS OTHERWISE STATED
4. ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED
5. FUTURE OPTION

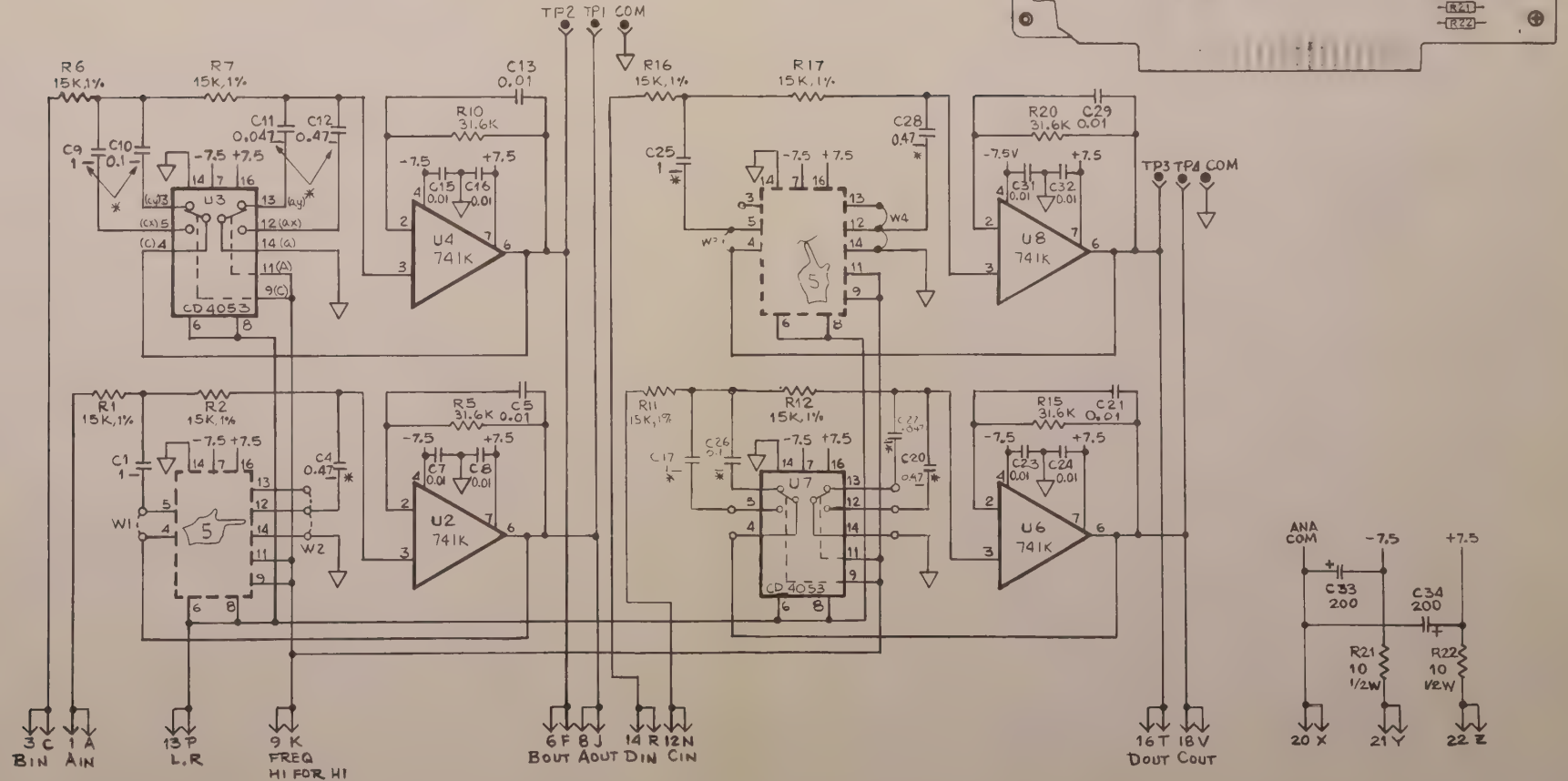


Figure 5-9. Part No. 41221 (Old)

ACTIVE FILTER CIRCUIT ASSEMBLY (Part No. 42978) (New)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C9, C17, C25	Capacitor, 1 μ F, 200V	18843
C4, C12, C20, C28	Capacitor, 0.47 μ F, 100V	13238
C5, C7, C8, C13, C15, C16, C21, C23, C24, C29, C31, C32, C35-38	Capacitor, 0.01 μ F, 50V, Disc	12144
C10, C26	Capacitor, 0.1 μ F, 200V	12121
C11, C27	Capacitor, 0.047 μ F, 200V	12239
C33, C34	Capacitor, 200 μ F, 15V	15838
R1, R2, R6, R7, R11, R12, R16, R17	Resistor, 15k Ω , 1%	21198
R5, R10, R15, R20	Resistor, 31.6k Ω , 1%, 1/4W	21745
R21, R22	Resistor, 10 Ω , 10%, 1/2W	02039
R23	Resistor, 1k Ω , ESI, QB, 0.01%	27193
R24	Resistor, 9k Ω , ESI, QB, 0.01%	22032
R25	Trimpot, 20k Ω	21199
R26	Resistor, 10M Ω , 1/4W, 10%	13974
U2, U4, U6, U8	Op Amp, 741K	21625
U3, U7	IC, CD4053	20744
U9	Op Amp, LH0044CH	28187
W1-W4	Wire	06091
	Shield, PCB	41469
	Socket, 8 PIN	22410

NOTES:

1. * ARE THE LINES OUTSIDE OF FOIL
2. ALL RESISTOR VALUES ARE IN OHMS
3. ALL RESISTORS ARE 1/4 W 10% UNLESS OTHERWISE STATED
4. ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED
- 5 FUTURE OPTION

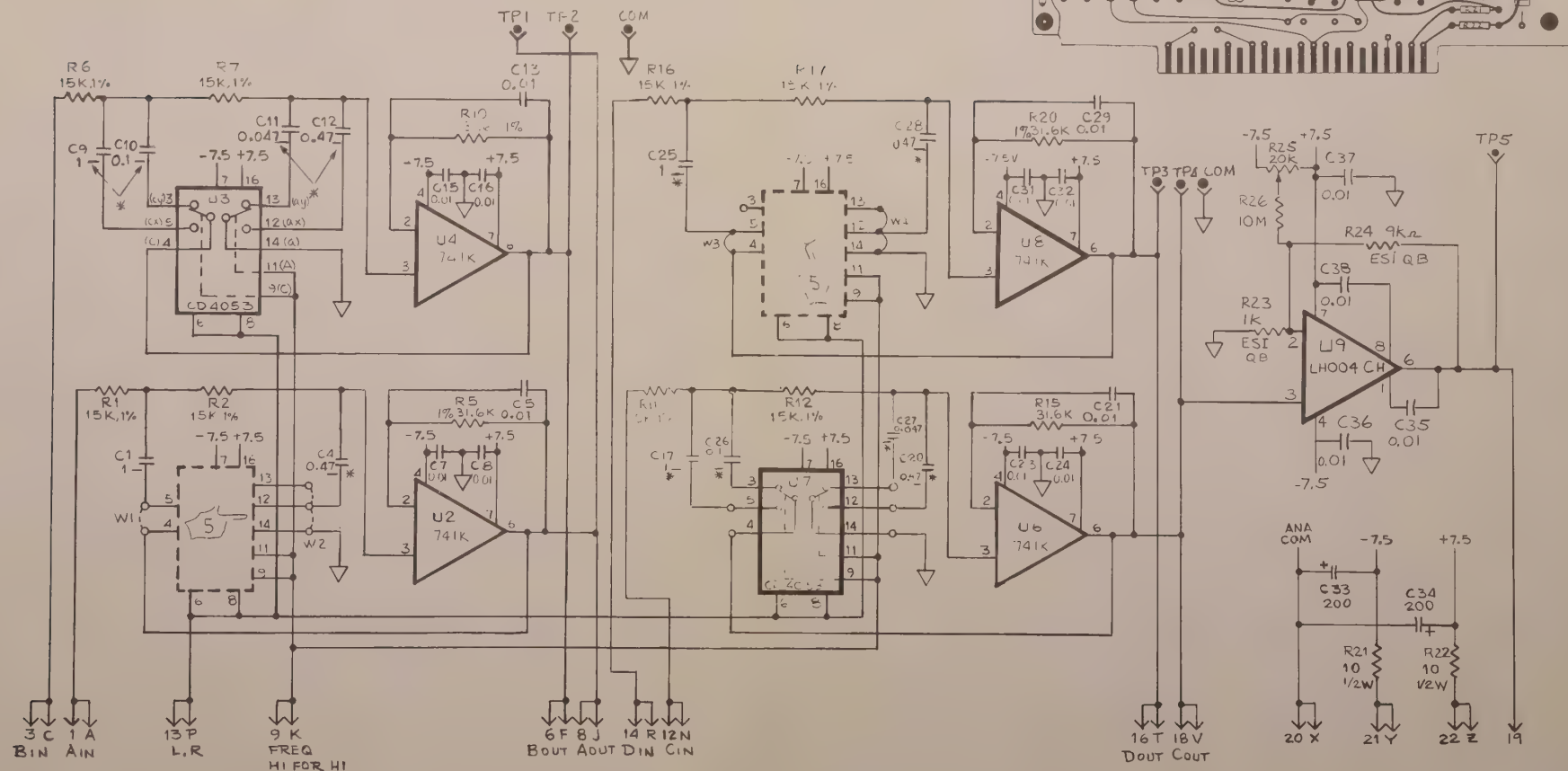
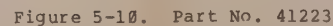


Figure 5-10. Part No. 42978 (New)

5.11 RANGE BOARD CIRCUIT ASSEMBLY (Part No. 41223)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C3	Capacitor, 100pF, 500V	18760
C4	Capacitor, 0.001μF, 500V	07094
C5	Capacitor, 0.01μF, 100V	12260
C6	Capacitor, 0.1μF, 200V	12121
C7, C12	Capacitor, 39μF, 10V	06473
C8, C11	Capacitor, 0.01μF, 50V, Disc	12144
C9	Capacitor, 25pF, 1kV, Disc	01924
C10	Capacitor, 8pF Disc	02127
K1-K3	Relay, GB-822A-2	26667
K4-K6	Relay, GB-821A-4	27841
Q1-Q4	Transistor, 2N3704	12077
Q5	Transistor, 2N3702	12041
R1	Resistor, 100kΩ, 0.01%, ±5ppm/°C, ESI F, Bobbin	42547
R3	Resistor, 11.111Ω, 0.01%, ±5ppm/°C, ESI QB	41680
R4, R21, R29	Resistor, 1kΩ, 10%, 1/4W	13920
R5	Resistor, 1.0101kΩ, 0.01%, ±5ppm/°C, ESI QB	41679
R6, R22, R24, R28	Resistor, 100Ω, 10%, 1/4W	13907
R7	Resistor, 100.100Ω, 0.01%, ±5ppm/°C, ESI QB	41678
R8, R14	Resistor, 10Ω, 10%, 1/4W	13895
R9-R12	Resistor, 40Ω, 0.01%, ±5ppm/°C, ESI QB	41677
R13	Resistor, 1Ω, 10%, 1/2W	12448
R15-R20	Resistor, 68Ω, 10%, 1/4W	13902
R23, R25-R27, R30	Resistor, 2.2kΩ, 10%, 1/4W	13924
R31	Resistor 10kΩ, 10%, 1/4W Mylar cover, style Q	75306
U1	Op-Amp 301	20669
U2	IC 4066AE	41761
	Shield, PCB	41469
	Socket, 14 Pin	19189

1. * LINED SIDE OUTSIDE OF FILM
2. ALL RESISTOR VALUES ARE IN OHMS
3. ALL RESISTORS ARE 1/4W 10% UNLESS OTHERWISE STATED
4. ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED



5.12 PREAMP AND LEVEL REGULATOR CIRCUIT ASSEMBLY (Part No. 41225)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C2, C9, C10, C19	Capacitor, 0.01 μ F, 50V, Disc	12144
C3	Capacitor, 4pF, 500V, Disc	02126
C4, C34	Capacitor, 0.05 μ F, 50V, Disc	12116
C11, C12,	Capacitor, 4.7 μ F, 50V	25965
C13, C29, C33	Capacitor, 1 μ F, 35V	06472
C14, C20, C22	Capacitor, 0.1 μ F, 200V	12121
C16, C18	Capacitor, 0.001 μ F, 1kV, Disc	21215
C21	Capacitor, 0.01 μ F, 100V	12260
C24, C23	Capacitor, 25pF, 1kV, Disc	01924
C26	Capacitor, 0.22 μ F, 200V	12238
C30, C31	Capacitor, 100 μ F, 12V	06157
C32	Capacitor, 2.2 μ F, 20V, Tant	13283
C35	Capacitor, 8pF, Disc	02127
CR1, CR2	Diode, MPD300	13639
CR3-CR6, CR10	Diode, 1N914	12356
CR9	Diode, 1N4734	12258
K1-K4	Relay, GB822A-2	26667
Q1-Q4	Transistor, 2N3704	12077
Q5	Transistor, 2N3702	12041
R1	Resistor, 10M Ω , 10%, 1/4W	13974
R2, R3	Resistor, 2.7 Ω , 10%, 1/4W	13837
R4, R19, R36	Resistor, 1k Ω , 10%, 1/4W	13920
R5-R8, R28, R34	Resistor, 4.7k Ω , 10%, 1/4W	13927
R9, R10	Resistor, 68 Ω , 10%, 1/4W	13902
R11	Resistor, 2.7k Ω , 10%, 1/4W	13925
R12, R14, R15	Resistor, 10k Ω , 1%, 1/4W	21740
R13	Resistor, 20k Ω , 1%, 1/4W	21743
R16	Resistor, 100k Ω , 1%, 1/4W	21750
R17	Trimpot, 50k Ω	12091
R18, R24	Resistor, 100 Ω , 10%, 1/4W	13907
R20	Resistor, 470 Ω , 10%, 1/4W	13915
R21, R22	Resistor, 82k Ω , 10%, 1/4W	24812
R23	Resistor, 270k Ω , 10%, 1/4W	20432
R25	Resistor, 100k Ω , 10%, 1/4W	13945
R26, R27	Resistor, 10 Ω , 10%, 1/2W	02039
R30	Resistor, 5.6k Ω , 10%, 1/4W	13928
R31, R33	Resistor, 1M Ω , 10%, 1/4W	13960
R32, R38	Resistor, 15k Ω , 10%, 1/4W	13935
R35	Resistor, 22k Ω , 10%, 1/4W	13937
R37	Trimpot, 1k Ω	18469
R39	Resistor, 10 Ω , 10%, 1/4W	13895
U1, U9	Op-Amp, 301	20669
U2, U5, U6	Op-Amp, 741	20668
U3	IC, CD4053	20744
U4	IC, CD4066AE	41761
U7, U8	Op-Amp, CDA3080	20723
	Shield, PCB	41469
	Socket, 8 Pin DIP	22410

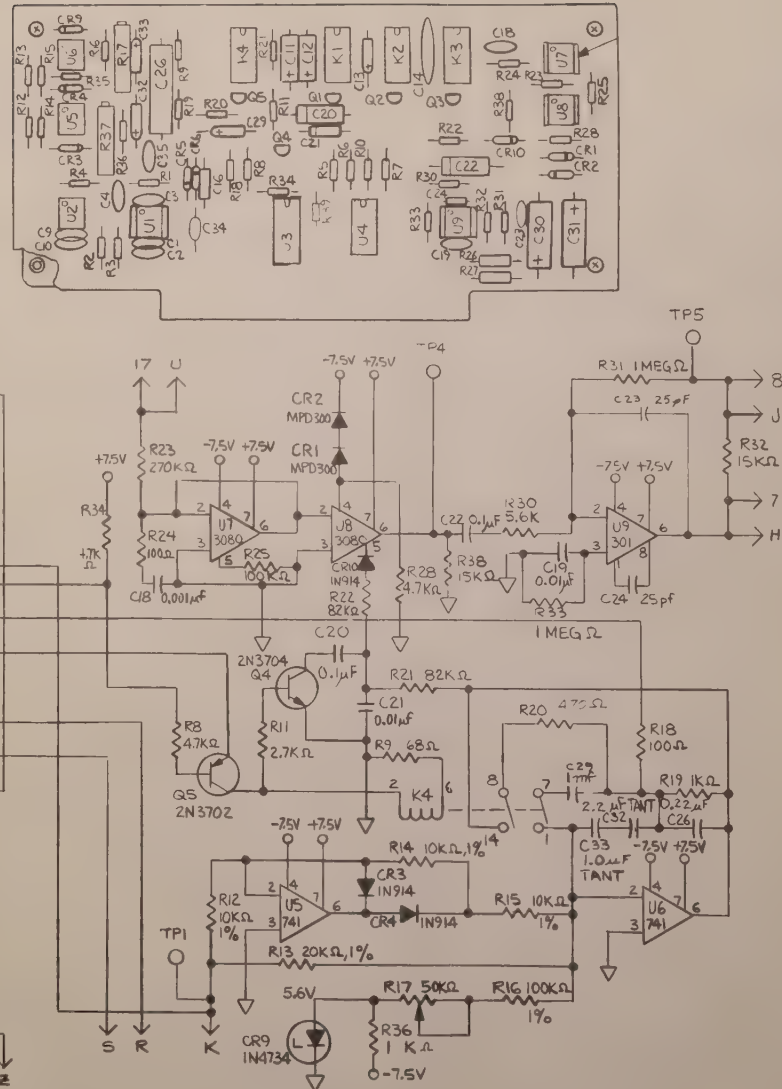
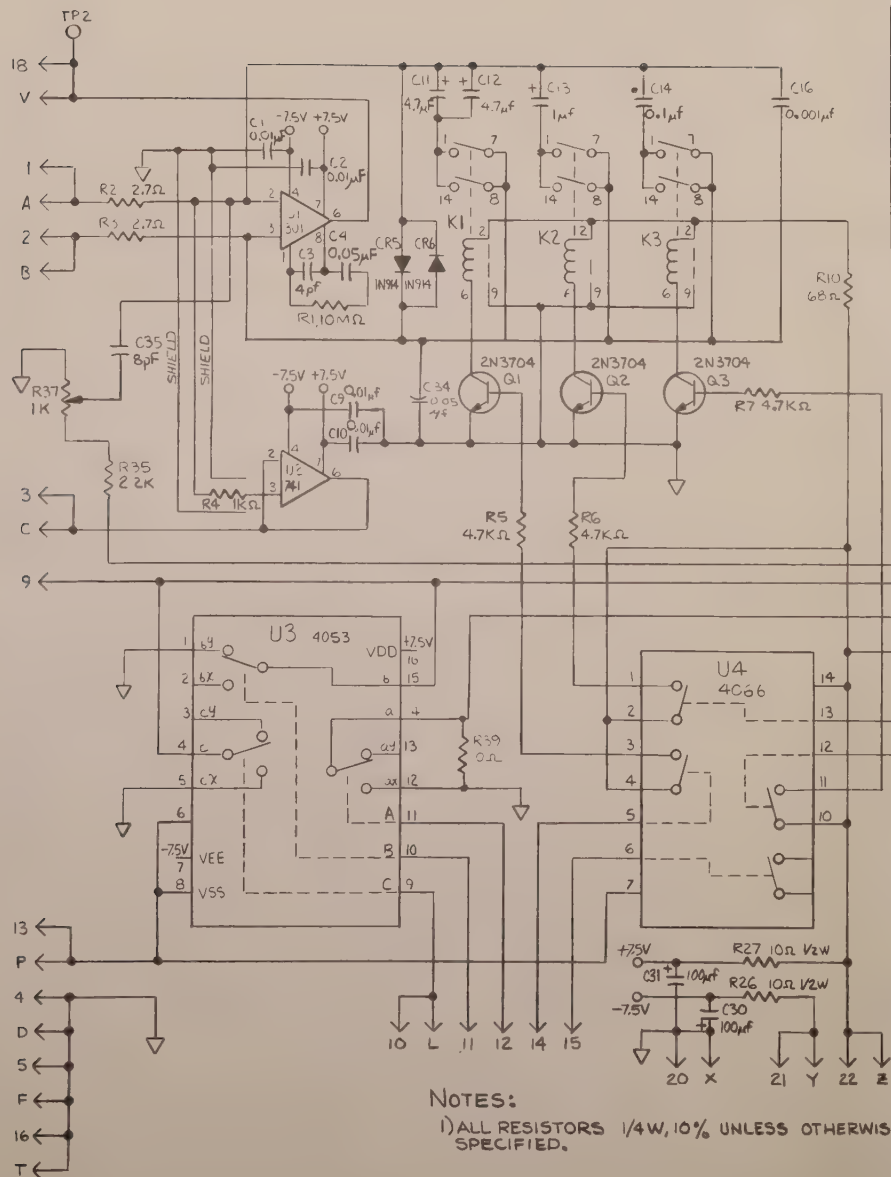
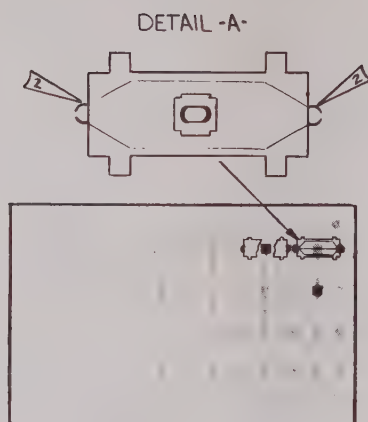


Figure 5-11. Part No. 41225

5.13 KEYBOARD CIRCUIT ASSEMBLY (Part No. 41269)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
	Keyboard Switch	41656
	Switch Contact	41655



NOTE:

1. INSTALL SWITCH CONTACT (ITEM 3) TO MOUNT FLUSH AGAINST PCB AND ALIGNED WITH SWITCH (ITEM 2), SEE DETAIL A.
2. INSTALL SWITCH (ITEM 2) USING TOOL #41269 (REWORKED MANUFACTURE SUPPLIED TOOL). IF HAND INSTALLATION IS NECESSARY, APPLY PRESSURE ON SWITCH MTG BARREL , DO NOT PRESS IN THE CENTER OF THE SWITCH.

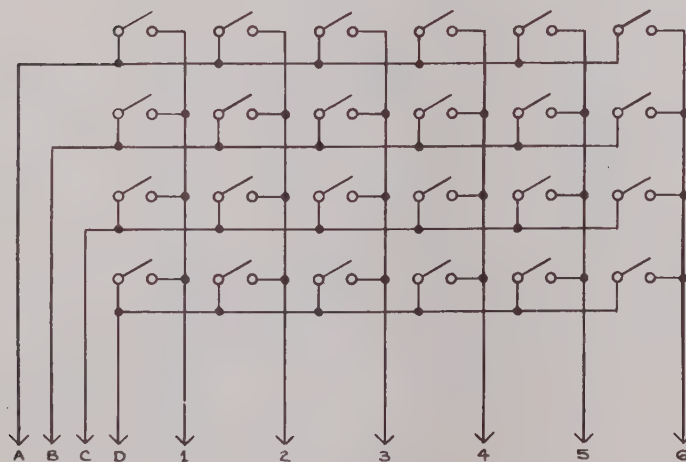


Figure 5-12. Part No. 41269

5.17 CPU BOARD CIRCUIT ASSEMBLY (Part No. 41491)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C2	Capacitor, 0.1 μ F, 200V, Mylar	12121
C3, C4	Capacitor, 100pF, 600V, Poly	18760
C5	Capacitor, 0.47 μ F, 50V	13653
C6-C8, C10	Capacitor, 0.01 μ F, 50V, Ceramic	12144
C9	Capacitor, 100 μ F, Electrolytic, 12V	06157
R1	Resistor, 3.3k Ω , 10%, 1/4W	13926
R2, R3	Resistor, 1M Ω , 10%, 1/4W	13960
R4-R6	Resistor, 1.2k Ω , 10%, 1/4W	13921
R7, R8	Resistor, 12.4k Ω , 1%, 1/4W, Metal Film	21741
R9	Resistor, 4.7k Ω , 10%, 1/4W	13927
R10	Resistor, 3.9k Ω , 10%, 1/4W	13929
U1-U4	CPU Prom Set	43714
U5	IC, 6800, Microprocessor	41290
U6, U7	IC, 6810, RAM	41291
U8	IC, 8602	41514
U10	IC, 7400	20600
U11	IC, 555, Timer	20721
U12	IC, MC3459, HI Cap Driver	41513
U13, U19	IC, 7442, Decoder	20608
U14-U17	IC, 8T97, Hex Bus Buffer	41515
	Socket, 24 Pin DIP, Solder Tail	41492
	Socket, 40 Pin DIP, Solder Tail	41342

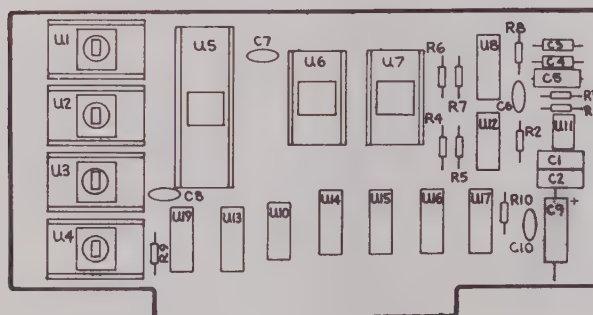


Figure 5-16. Part No. 41491

NOTES:

1. ALL RESISTORS ARE $\frac{1}{4}$ W, 10% AND MEASURED IN OHMS, UNLESS OTHERWISE SPECIFIED

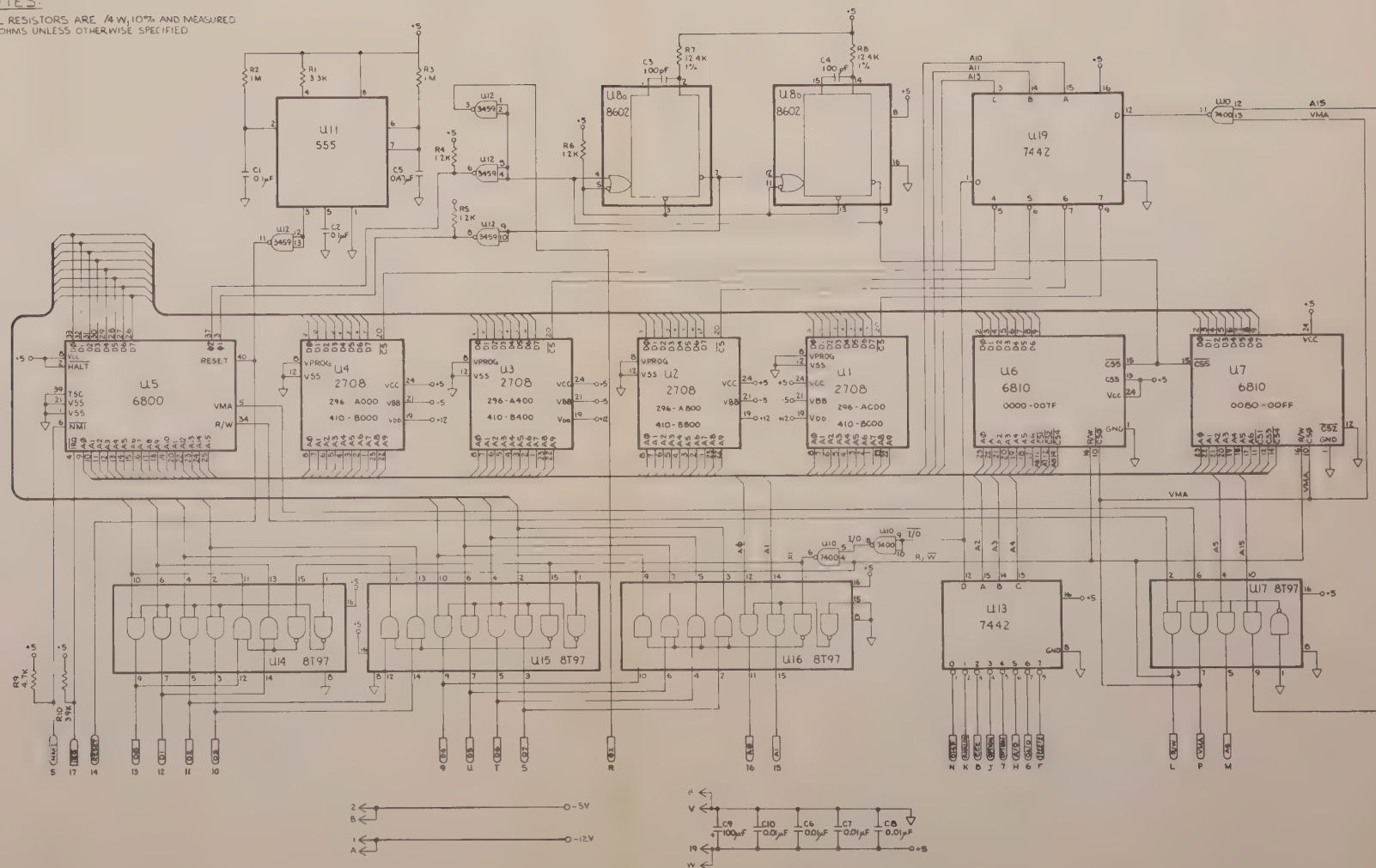
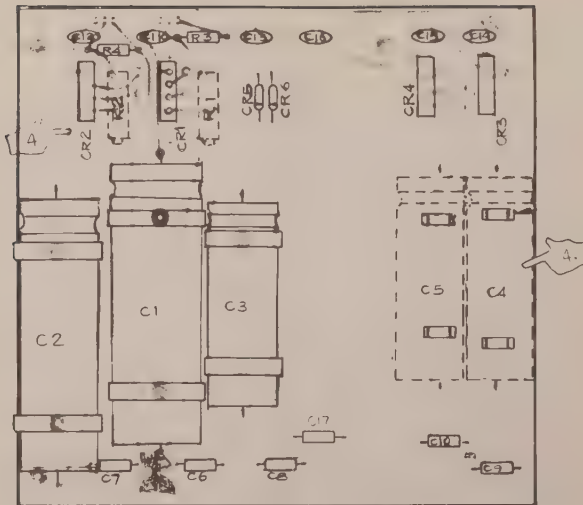
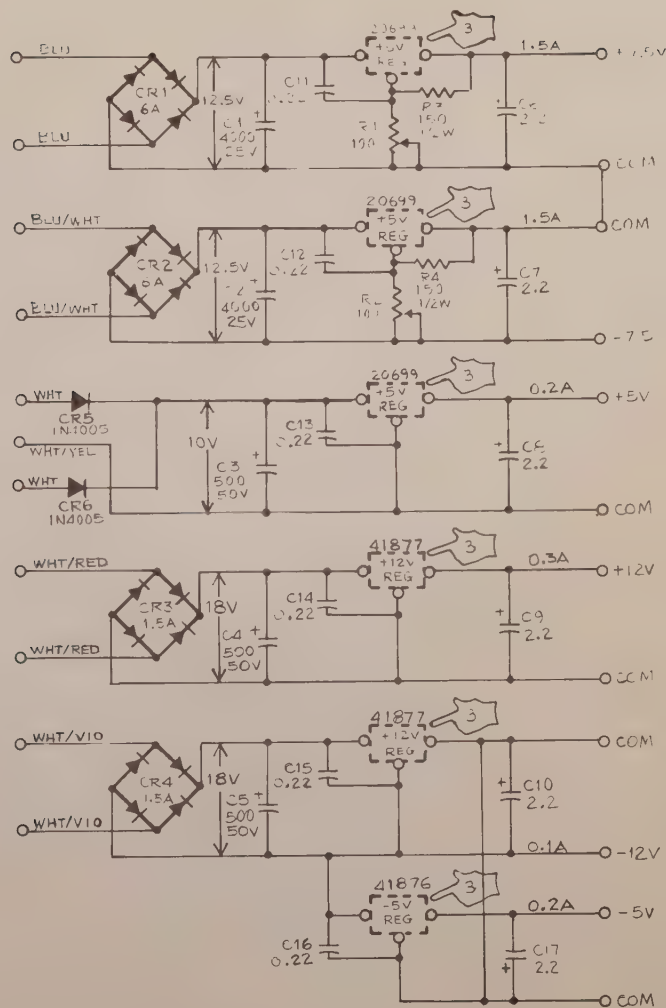


Figure 5-16. Part No. 41491
(Continued)

5.18 POWER SUPPLY CIRCUIT ASSEMBLY (Part No. 41693)

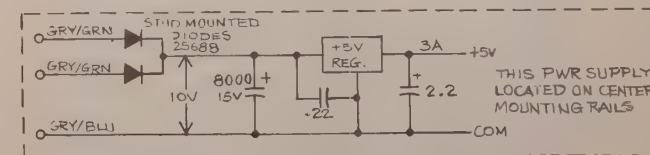
<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C2	Capacitor, 4000 μ F, 25V	26082
C3-C5	Capacitor, 500 μ F, 50V	01942
C6-C10, C17	Capacitor, 2.2 μ F, 20V, Tant	13283
C11-C16	Capacitor, 0.22 μ F, Disc	13680
CR1, CR2	Rectifier, Bridge, 6A, FLWD 200	27824
CR3, CR4	Rectifier, Bridge, 1.5A	21236
CR5, CR6	Diode, 1N4005	01779
R1, R2	Trimpot, 100 Ω	26853
R3, R4	Resistor, 150 Ω , 10%, 1/2W	15970

ALL VOLTAGES AT NOMINAL LINE AND FULL LOAD



NOTE:

- 1 ALL RESISTOR VALUES ARE IN OHMS
- 2 ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED
- 3 POWER SUPPLY COMPONENTS & SECTIONS NOTED BELOW ARE NOT LOCATED ON ASSY 41693 & ARE SHOWN FOR REF. ONLY (SEE ASSY 30296 FOR PARTS CALLOUT.)

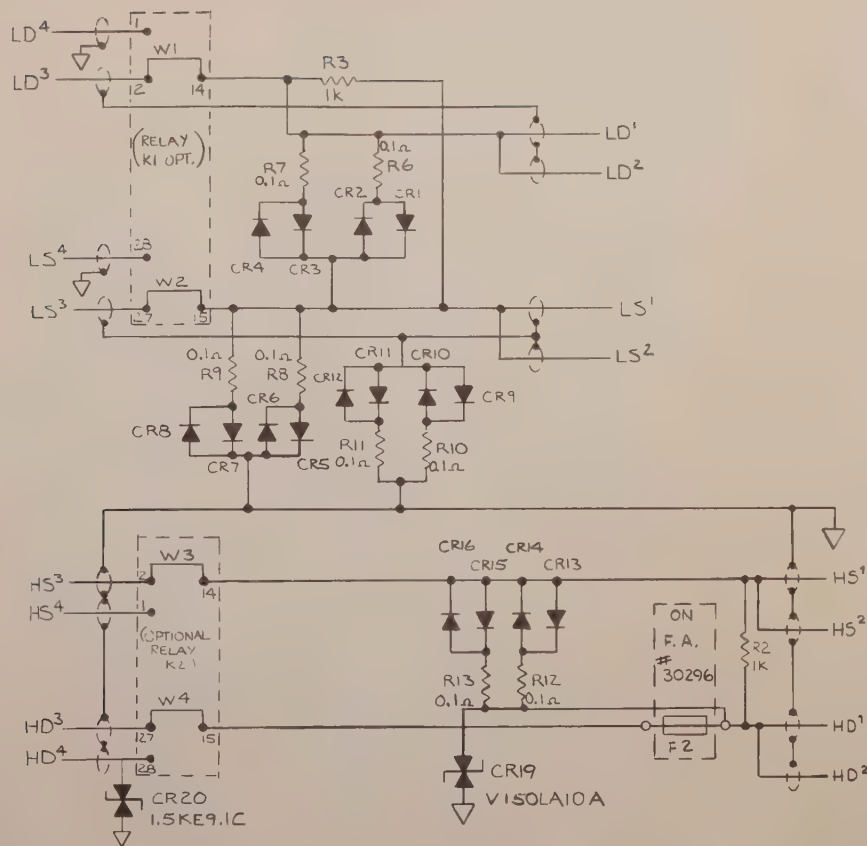


- 4 C4 AND C5 MOUNTED ON BACK SIDE OF BOARD. R1 AND R2

Figure 5-16, Part No. 41693.

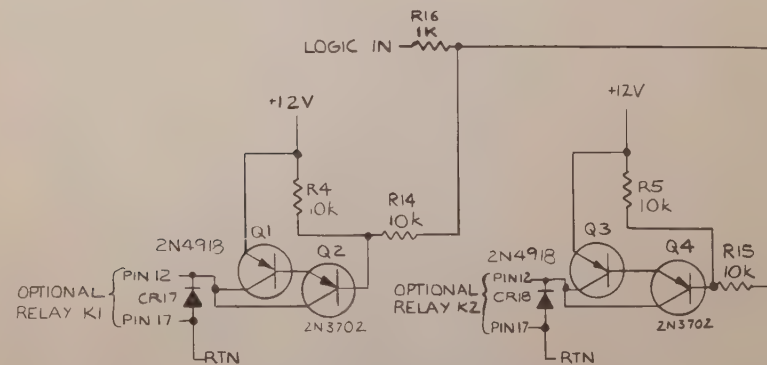
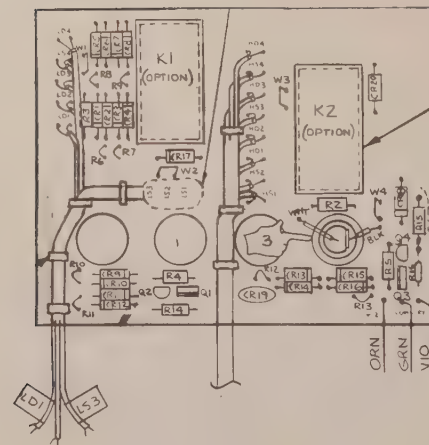
5.19 PROTECTION BOARD CIRCUIT ASSEMBLY (Part No. 42675)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
CR1-CR18	Diode, 1N4005	01779
CR19	Surge Protector, V150LA, 10A	42633
CR20	Surge Protector, 8V	42632
Q1, Q3	Transistor, 2N4918	18753
Q2, Q4	Transistor, 2N3702	12041
R2, R3, R16	Resistor, 1k Ω , 10%, 1/4W	307-13920
R4, R5, R14, R15	Resistor, 10k Ω , 10%, 1/4W	13933
R6-R13	Resistor, 0.1 Ω , Manganin	05937
W1-W4	Wire	06090
	Sockets, Special Modified, 28 Pin	26859



NOTES:

4. ALL DIODES, EXCEPT CR19, 20, 21 ARE IN4005.
5. R6-13 ARE MANGANIN RESISTOR STOCK.
6. R2, 3, 4, 5, 14 & 15 ARE 1/4W, ±10%

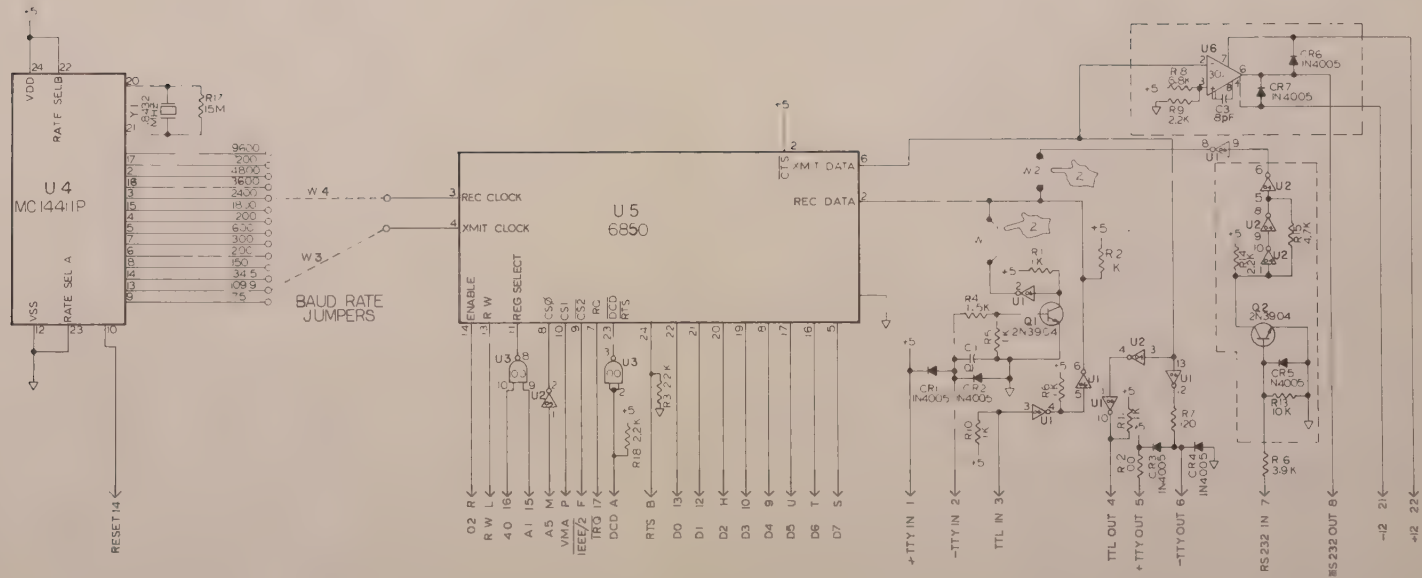


DRIVER CKTS FOR OPTIONAL RELAYS

Figure 5-17. Part No. 42675

B.2 Teletype Interface Circuit Assembly (Part No. 42763)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 0.1 μ F, Disc, 100V	24395
C3	Capacitor, 8pF, Disc Ceramic	02127
C4	Capacitor, 100 μ F, 25V, Electrolytic	13683
CR1-7	Diode, 1N4005	01779
Q1, Q2	Transistor, 2N3904	18751
R1, R2, R5, R6, R10, R11	Resistor, 1k Ω , 1/4W, 10%	13920
R3, R9, R14, R18	Resistor, 2.2k Ω , 1/4W, 10%	13924
R4	Resistor, 1.5k Ω , 1/4W, 10%	13922
R7	Resistor, 120 Ω , 1/4W, 10%	13908
R8	Resistor, 6.8k Ω , 1/4W, 10%	13930
R12	Resistor, 100 Ω , 1/4W, 10%	13907
R13	Resistor, 10k Ω , 1/4W, 10%	13933
R15	Resistor, 4.7k Ω , 1/4W, 10%	13927
R16	Resistor, 3.9k Ω , 1/4W, 10%	13929
R17	Resistor, 15M Ω , 1/4W, 10%	13976
U1	IC, 7406, TTL	20678
U2	IC, 7404, TTL	20695
U3	IC, 7400, TTL	20600
U4	4411, Baud Rate Gen	42933
U5	6850, ACIA	42968
U6	Op Amp, 301	20669
Y1	Crystal, 1.8432MHz, 0.05%	43268
	Socket, 24 Pin	41492
	Socket, Crystal, HC6-U Size	24444
	Socket, 8 Pin	22410
	Socket, 14 Pin	19189



NOTES:

1. SOFTWARE MUST BE WRITTEN FOR ± 16 CLOCK IN ACIA.

2. J1 INSTALLED FOR TTY (20 MA LOOP).
J2 INSTALLED FOR RS232.
NO JUMPER INSTALLED FOR TTL.

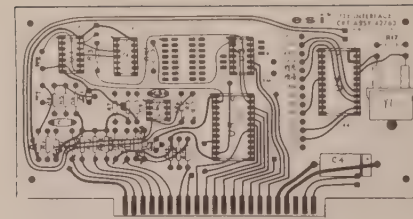
3. ALL RESISTORS ARE $\frac{1}{4}$ W 10% & IN OHMS UNLESS OTHERWISE SPECIFIED.

4. ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE SPECIFIED.

BAUD RATE	FREQUENCY
9600	153.6 K
2400	5.2 K
4800	76.6 K
3600	57.6 K
2400	36.4 K
800	29.8 K
1200	19.2 K
600	9600
300	4800
200	3200
150	2400
134.5	2.53 K
109.9	1.758 K
75	1.200

	RS232	TTL DATA	TTY DATA
MARK	-12	+5	20MA
SPACE	+12	$\emptyset$ V	$\emptyset$ MA

Figure B-3. Part No. 42763

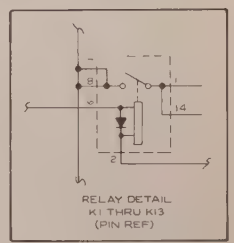
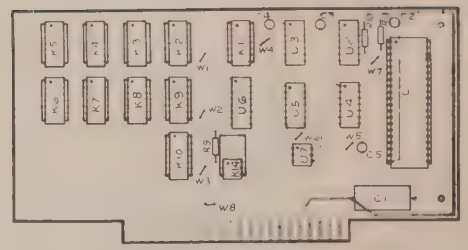
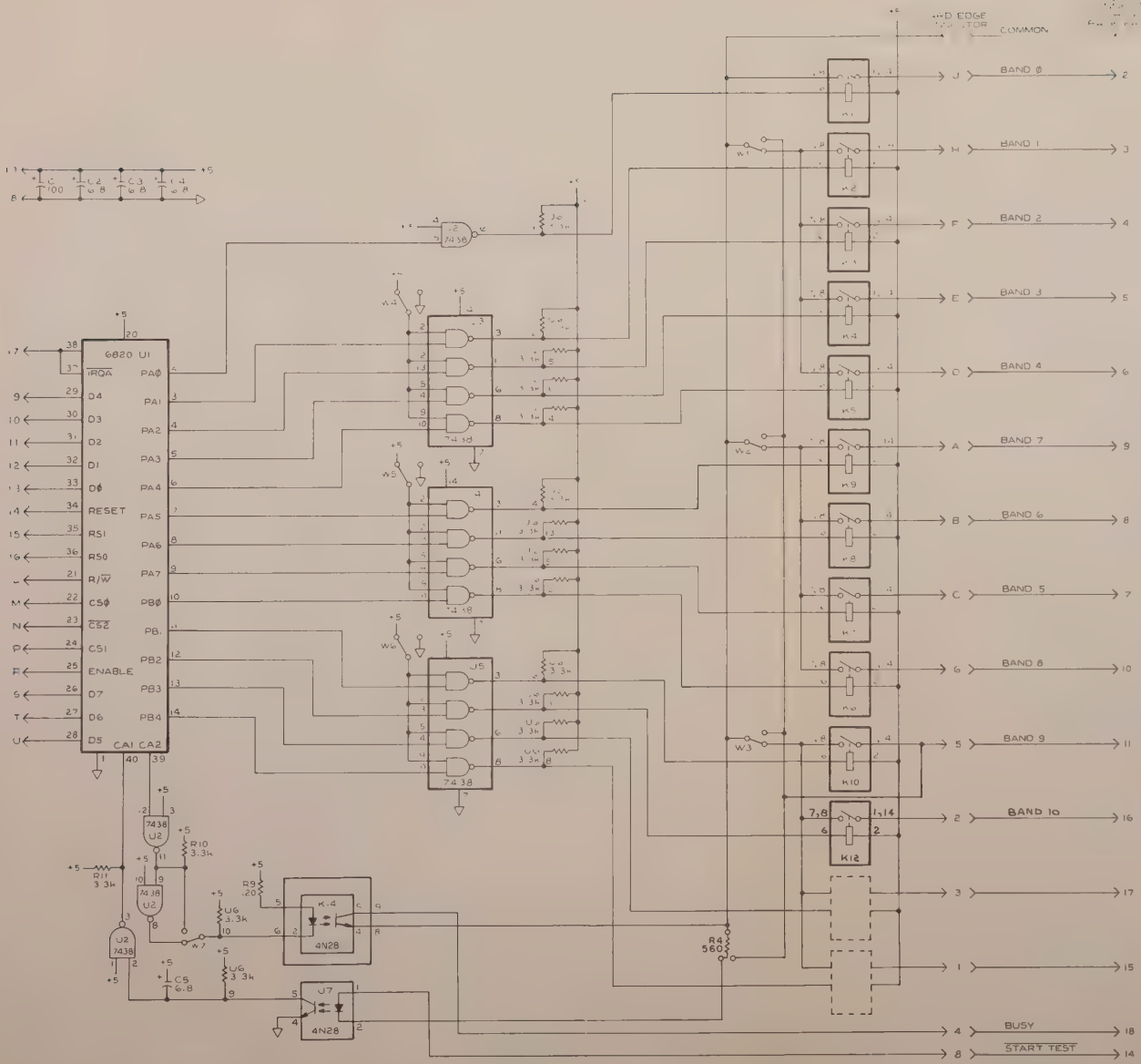
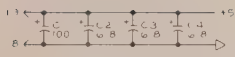


B.3 Card Reader Interface Circuit Assembly (Part No. 43399)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 6.8 μ F, Tant, 35V	25339
R1-R3	Resistor, 3.3k Ω , 10%, 1/4W	13926
U1	IC, 6820, PIA	41292
U2, U4	IC, 7423	43845
U3	IC, 7400	20600
U5	IC, 7402	20604
	Socket, 40 Pin DIP	41342

B.5 Optional Interface Circuit Assembly, Daymarc, (Part No. 44256)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 100 μ F, 25VDC, Elect.	13683
C2-5	Capacitor, 6.8 μ F, Tant	43792
K1-10, K12	Relay, GB821A-4	24804
R4	Resistor, 560 Ω , 10%, 1/4W	13916
R9	Resistor, 120 Ω , 10%, 1/4W	13908
R10, 11	Resistor, 3.3k Ω , 10%, 1/4W	13926
U1	IC, 6820, MOS, 40 Pin	41292
U2-U5	IC, 7438	20718
U6	Resistor Pack, 3.3k Ω , DIP	22947
U7, K14	Optical Isolator, 4N28	20674
W1-W8	Wire, Bus, #22	06091
	Socket, 14 Pin DIP	19189
	Socket, 40 Pin DIP	41342



NOTE:

1. ALL RESISTOR VALUES ARE IN OHMS, 1/4W, 10% UNLESS OTHERWISE STATED.
2. ALL CAPACITORS ARE IN μ F UNLESS OTHERWISE STATED.
3. SEE LIMITS SECTION OF INSTRUMENT MANUAL FOR DESCRIPTION OF THESE FUNCTIONS.

Figure B-6. Part No. 44256

B.6 Optional Interface Circuit Assembly, Deval, (Part No. 44257)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1	Capacitor, 100 μ F, 25VDC, Elect	13683
C2-C5	Capacitor, 6.8 μ F, Tant	43792
K1-K10, K12	Relay, GB821A-4	24804
K14	Optical Isolator, TIL119	44224
R9	Resistor, 120 Ω , 10%, 1/4W	13908
R10, R11	Resistor, 3.3k Ω , 10%, 1/4W	13926
U1	IC, 6820, MOS, 40 Pin	41292
U2-U5	IC, 7433	20718
U6	Resistor Pack, 3.3k Ω , DIP	22947
U7	Optical Isolator, 4N28	20674
W1-W3	Wire, Buss, #22	06091
	Socket, 14 Pin DIP	19189
	Socket, 40 Pin DIP	41342

B.7 DC Resistance Circuit Assembly (Part No. 42596)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C1, C2	Capacitor, 39 μ F, Tant, 10V	06473
C3, C16, C17,		
C19, C20	Capacitor, 0.01 μ F, Disc, 50V	12144
C13	Capacitor, 0.22 μ F, Mylar	12238
C14	Capacitor, 0.47 μ F, Disc, 10V	20652
C15	Capacitor, 0.05 μ F, Disc, 50V	12116
CR1	Diode, 1N4005	01779
CR2-CR14	Diode, 1N914A	12356
K1-K3	Relay, DIP, 1 Form A	27841
K4-K6	Relay, DIP, 2 Form A	26667
K7	Relay, Thermosen, DM2C	41517
Q1-Q4, Q9	Transistor, 2N3704	12077
Q5, Q7	Transistor, 2N3904	18751
Q6, Q8	Transistor, 2N3906	18754
R1, R49	Resistor, 100 Ω , 10%, 1/4W, CC	13907
R2, R8, R19, R40	Resistor, 1k Ω , 10%, 1/4W, CC	13920
R3, R9, R10, R20,		
R21, R26, R28-30	Resistor, 10k Ω , 10%, 1/4W, CC	13933
R4, R44	Resistor, 100k Ω , 10%, 1/4W, CC	13945
R5, R17, R18	Resistor, 5.6k Ω , 10%, 1/4W, CC	13928
R6	Resistor, 4.7k Ω , 10%, 1/4W, CC	13927
R7, R46	Resistor, 220 Ω , 10%, 1/4W, CC	13911
R11, R14	Trimpot, 200 Ω	12083
R12, R15	Resistor, 9.9k Ω , ESI QB, $\pm$ 0.01%	43292
R16	Resistor, 1k Ω , ESI QB, $\pm$ 0.01%	43293
R22, R31	Resistor, 588.24 Ω , ESI QB, $\pm$ 0.01%	43285
R23, R32	Resistor, 4.4118k Ω , ESI QB, $\pm$ 0.01%	43288
R24, R33	Resistor, 15k Ω , ESI QB, $\pm$ 0.01%	43295
R25, R34, R13	Resistor, 10k Ω , ESI QB, $\pm$ 0.01%	43294
R27	Trimpot, 20k Ω	21199
R35	Resistor, 10 Ω , ESI QB, $\pm$ 0.01%, 4T	43284
R36	Resistor, 1.0010k Ω , ESI QB, $\pm$ 0.01%	43287
R37	Resistor, 111.111k Ω , F Bobbin, $\pm$ 0.01%	43291
R38	Resistor, 1M Ω , F Bobbin, $\pm$ 0.01%	73103
R39, R42	Resistor, 470 Ω , 10%, 1/4W, CC	13915
R41	Resistor, 22M Ω , 10%, 1/4W, CC	13978
R43	Resistor, Select	
R45	Trimpot, 50k Ω	12091
R47, R48	Resistor, 10 Ω , 10%, 1/2W, CC	02039
U1, U5	Op Amp, LH0044	28187
U2	Op Amp, 356A	42816
U3, U4	Op Amp, 356	41473
U6-U8	CMOS Switch, CD4052	20743
U9	PIA, 6820	41292
U10	Hex Inverter, 7406	20678
W1-W3	Coaxial Wire	06260
W4	Wire	06185
	Socket, 14 Pin	19189
	Socket, 40 Pin	41342
	Socket, 8 Pin DIP	22410

Diagram showing a relay assembly with terminals 8, 9, 10, 11, 12, 13, and 4. The assembly includes a switch (K1), a coil (Z), and a diode (3).

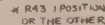
K1.2.3



K4, 5, 6



7



CRIZ, IN 914

Q9
N3704

(TO RELAY DRIVERS) 4 ←



1. C3-C6 ARE BYPASS CAPACITORS
ON U1 + U5
2. ALL CAPACITOR VALUES ARE MFD,
3. ALL DIODES ARE IN914A EXCEPT AS NOTED.
4. ALL RELAYS SHOWN IN DE-ENERGIZED POSITION
5. RELAYS ARE ACTUATED AS FOLLOWS:
K1 & K4 ACTUATED BY Q1
K2 & K5 ACTUATED BY Q2
K3 & K6 ACTUATED BY Q3
6. ALL RESISTORS ARE IN OHMS & 1/4W 10%
UNLESS OTHERWISE SPECIFIED.

B - 15

5100 SOLID STATE NULL DETECTOR CALIBRATION PROCEDURE

This procedure is provided to calibrate the Solid State Null Detector, part number 400385, that replaces the chopper Null Detector originally used in the early Model 5100's. See Fig. 1 for location of adjustments.

Equipment required:

1. Adjustment tool - insulated blade type
2. Null Detector - Fluke 845AR
3. Extender board and cables - Dana p/n 400913
4. Dekavider - ESI DV411
5. Oscilloscope - Tektronic RM503
6. DC Power Supply - Cohu 326
7. 10 Kilohm decoupling resistor, 1/4W, 5%
8. Test leads, assorted
9. 2-pin Winchester Connector - Dana p/n 600080

This procedure is separated into four parts; these are labelled as follows:

1. Isolator Voltage and Current Zero
2. Null Detector Common Mode Adjustment
3. Manual Threshold Tracking Gain Adjustment
4. Null Detector Zero Adjustment

I. Isolator Voltage and Current Zero

1. Turn off the AC power to the DVM
2. Insert the extender board into the Null Detector slot and connect the extender cables to the 10K Decade, Null Detector inputs (red & black), and insert a 2-pin Winchester plug into the filter input on the Null Detector
3. Turn on the AC power to the DVM
4. Short the input signal leads together

5. Connect a Null Detector "plus" lead to the lower pin on the filter plug. Connect the "minus" lead to the shorted input leads. Connect a clip lead from the shorted input leads and Null Detector "minus" lead to the top pin of the plug on the filter input of the DVM Null Detector.
6. Obtain a reading of "+" and all zeroes on the 10 range in "DC" and switch the mode to "command". Threshold control should be fully clockwise.
7. Turn the operate switch to "on" on the Null Detector and read the isolator voltage offset. Adjust the "isolator zero" on the side of the DVM Null Detector, R-3, for zero ± 10 microvolts.
8. Remove the clip lead from the upper pin on the filter input on the Null Detector and read the isolator current offset. Adjust the "isolator current zero", R-22, on the bottom apron on the front of the DVM Null Detector for the same offset as in Step 7.
9. Because the voltage and current zeroes interact with adjustment, Steps 7 and 8 should be adjusted for zero ± 10 microvolts deflection on the Null Detector with the clip lead on (Step 7) and off (Step 8).
10. Remove the Null Detector leads, the clip lead, and the 2-pin plug from the filter input on the Null Detector.

II. Null Detector Common Mode Adjustment

Note: the "threshold" control on the DVM changes the current gain in the comparator amplifier (Null Detector) from high gain (full CW) to low gain (full CCW). When the "threshold" control is rotated from stop to stop the comparator amplifier's DC level must remain stationary to maintain linear operation while changing the current gain in the comparator amplifier.

1. Turn off the AC power to the DVM.
2. Remove the Null Detector from the extender board and disconnect the cables.

3. Solder a 10 Kilohm, 1/4W, 5% decoupling resistor to the bottom lug of the tracking gain potentiometer, R-86, on the "mother" board etch side. This is the comparator amplifier output.
4. Connect the Null Detector to the extender board, connect cables, and turn on the AC power to the DVM.
5. Obtain a "+" and all zeroes on the 10 range in DC and set the mode to "command."
6. Connect an oscilloscope vertical input to the decoupling resistor and the common lead to the Null Detector case. Note: DC couple the scope input.
7. Connect a shorting strap into two holes (vertical alignment) between the "DAC zero" and "CM" on the etch side of the "mother" board. Note: this shorts the collectors off the first stage in the comparator amplifier.
8. Rotate the "threshold" control from stop to stop and observe the DC level of comparator amplifier output on the oscilloscope.
9. Adjust "CM", R-32, for minimum DC shift when the "threshold" control is rotated from "CW" (high gain) to "CCW" (low gain). Leave the "threshold" control in the "CW" position. Note: R-32 may interact with the "DAC zero" adjustment, R-14, if there is a large adjustment required.
10. Remove the shorting strap from the holes on the side of the Null Detector module.
11. Observe the DC level on the scope and re-adjust R-14, "DAC zero", to bring the comparator amplifier output to the DC reference. Note: signal will be much noisier with the shorting strap disconnected.
12. Again short the collectors and repeat Step 9 through Step 11.
13. Remove the scope leads, the shorting strap and leave the "threshold" control in the CW position.

III. Manual Threshold Tracking Gain Adjustment

1. Put the DVM into the "manual threshold" mode.
2. Connect the DVM input lead to the Dekavider output and apply 1 Volt DC to the input of the Dekavider set to zeroes.
3. Rotate the lowest order bank for "5" digits on the DVM readout. Note the dial setting on the Dekavider. Decrease the dial slowly until a "4" appears and again note the dial setting. The difference should be 90 to 100 microvolts. Note: if the difference between a "4" and a "5" is less than 90 microvolts, the gain tracking is too high; if it is more than 100 microvolts, the tracking gain is too low. This adjustment can be done in either polarity.
4. Adjust R-86 CCW to increase the gain and CW to decrease the gain tracking.

IV. Null Detector Zero Adjustment

1. The DVM controls and test setup in the preceding test also apply to zeroing the Null Detector.
2. Adjust R-14, DAC zero, for the same Dekavider reading for a "5" on the DVM readout in both polarities. Note: R-14 may interact with R-86 depending upon the amount of adjustment necessary to zero the Null Detector. The Null Detector adjustment, R-14, assures that the output of the comparator amplifier will arrive at zero from either polarity with the least amount of offset (less than 1 digit). Part III and IV can be easily rechecked because the test setup is identical.

The only steps left to be done for complete DC calibration is to check the ratio linearity on the buffer (R-23) and to adjust the buffer gain (R-17) for a readout that is the same as a traceable DC input on the ten range as close to full scale as possible. The 100V, R-18, and 1000V, R-37, can then be adjusted on the Null Detector module against known inputs.

5100 SOLID STATE NULL DETECTOR

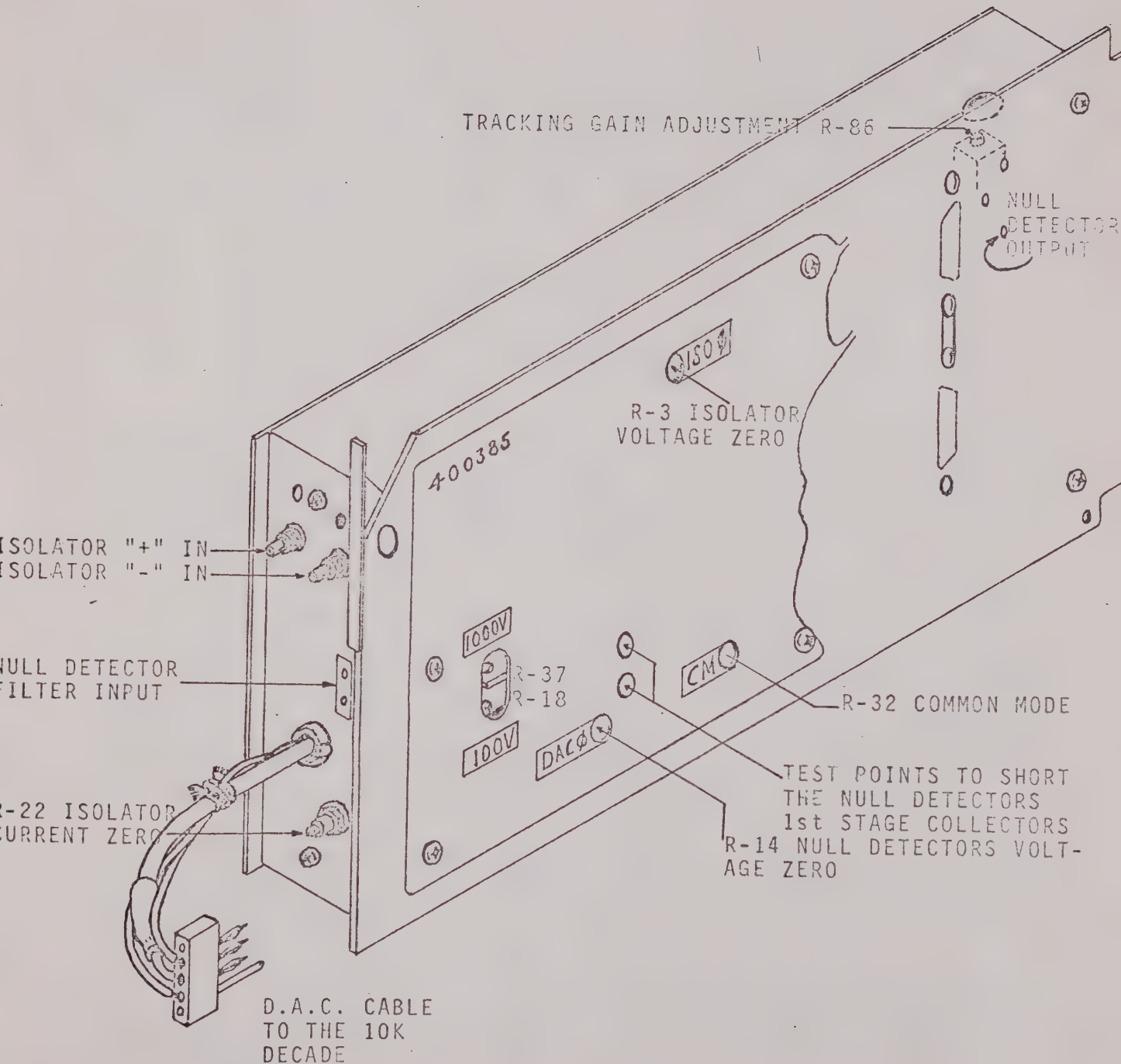


FIGURE 1.



Proper Use of KELVIN KLIPS®

(Use these)

KELVIN KLIPS are four-terminal connector clips designed to provide rapid, precise connections while eliminating errors due to test lead resistance. However, loss of accuracy may result when KELVIN KLIPS are used under certain measurement conditions. To ensure specified instrument accuracy, use a test fixture whenever:

- 1) $C < 100\text{pF}$
- 2) $L < 100\mu\text{H}$
- 3) $R > 1\text{M}\Omega$
- 4) $\text{Freq} > 10\text{kHz}$

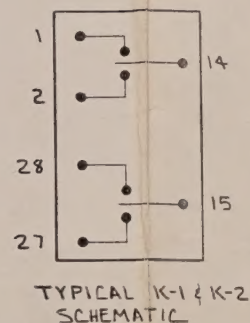
Before making a measurement with the KELVIN KLIPS, take a few moments to determine the approximate range of unknown values you will be measuring. This, along with the test frequency you select, will affect the decision to use KLIPS or a fixture.

Also, when performing a zero correction calibration with KELVIN KLIPS, be sure to maintain the position and spacing of the test leads and test clips (approximately the same distance from one another as they will be when measuring a component). Changes in test lead position affect stray capacitance and stray inductance. This makes a true zero correction more difficult to obtain.

Do not clamp KELVIN KLIPS together when performing a short circuit correction. Instead, use a low resistance shorting bar between KLIPS to "Close Unknown".

For more information on test leads, test fixtures and zero calibration, refer to the service manual or contact your ESI sales representative.





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Distribution Approval

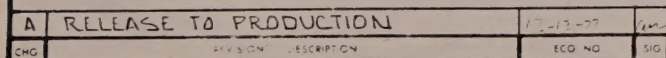
By, _____

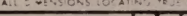
Date, DEC 16 1977

Distributed To _____

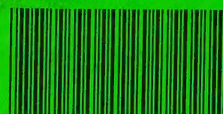
Customer (Name) _____

1. Install D. C. Resistance Converter, P. C. Assembly Part Number 42596, into location marked "Optional A/D" on the right side of the instrument (board #14, Figure 4.1 of manual).
2. Cut and remove jumpers W1, W2, W3 and W4 on Discharge Protection Board, Part Number 42675, located on rear panel.
3. Install mercury relays in sockets noting "up" marking on relay. Gently tap relay to shake down mercury before installing.
4. Install threaded spacer (item 5 on Bill of Materials) on screws projecting through Protection Board.
5. Install Lexan plastic piece (item 4 on Bill of Materials) on spacers using screws (item 7 on Bill of Materials) and lock washers (item 6 on Bill of Materials). This is to prevent relays from being vibrated loose.
6. Turn on instrument and allow 0.5 hr. warm-up time.
7. Check zero adjustments (section 4.1.1 of manual) and D. C. Resistance converter calibration (step 3 of section 4.1.2.1 of manual).



						ITEM	QTY REQD.	CAT. CLASS.	PART NO.	MATERIAL OR DESCRIPTION		FED. IDEN.
PROTECTIVE COATING						esi				Electro Scientific Industries Inc.		1183
						PORTLAND OREGON U.S.A. 97220						
DRAWING PRACTICE BASED ON MIL STD PC ALL DIMENSIONS LOCATING TRUE POSITION, ASS RAYC						TITLE CODE						
DR 						TOLERANCES UNLESS OTHERWISE NOTED FRACTIONAL						
PCD Cam						D.L. RESISTANCE OPTION						
42E36						PART NO. 42705						
W.P. NEXT ASST QTY USED ON APPD						CONTAINER BOOK NO.		CAT. CODE C 130	PART NO. 42705			
								SHEET		OF		

MP MASTER



MA29519